Instruments

HE MAGAZINE of MEASUREMENT and CONTROL

Vol. 24 JANUARY 1951 No. 1

CLUDING THE *Journal of the Instrument Society of America*

ND THE *Journal of the Southern California Meter Association*

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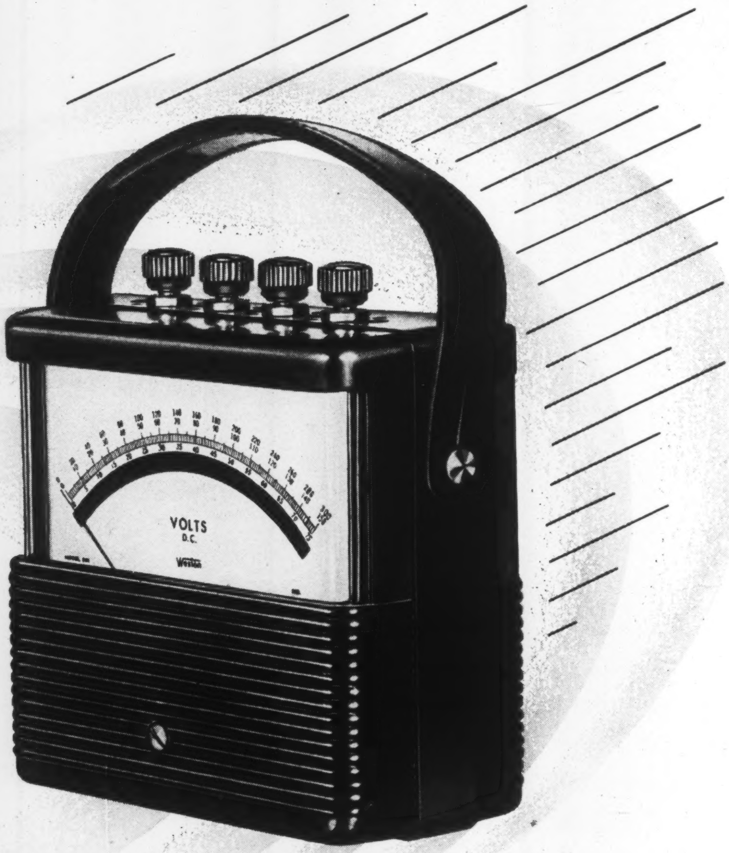
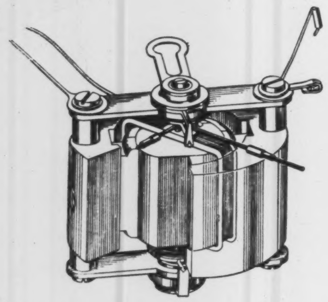
CALIBRATION OF A MUELLER BRIDGE AT THE NATIONAL BUREAU OF STANDARDS. (See article on page [illegible])

*Inherently SHIELDED

***The high degree of shielding obtained with the perfected WESTON core magnet mechanism renders Model 901 portables virtually immune to external magnetic fields.**

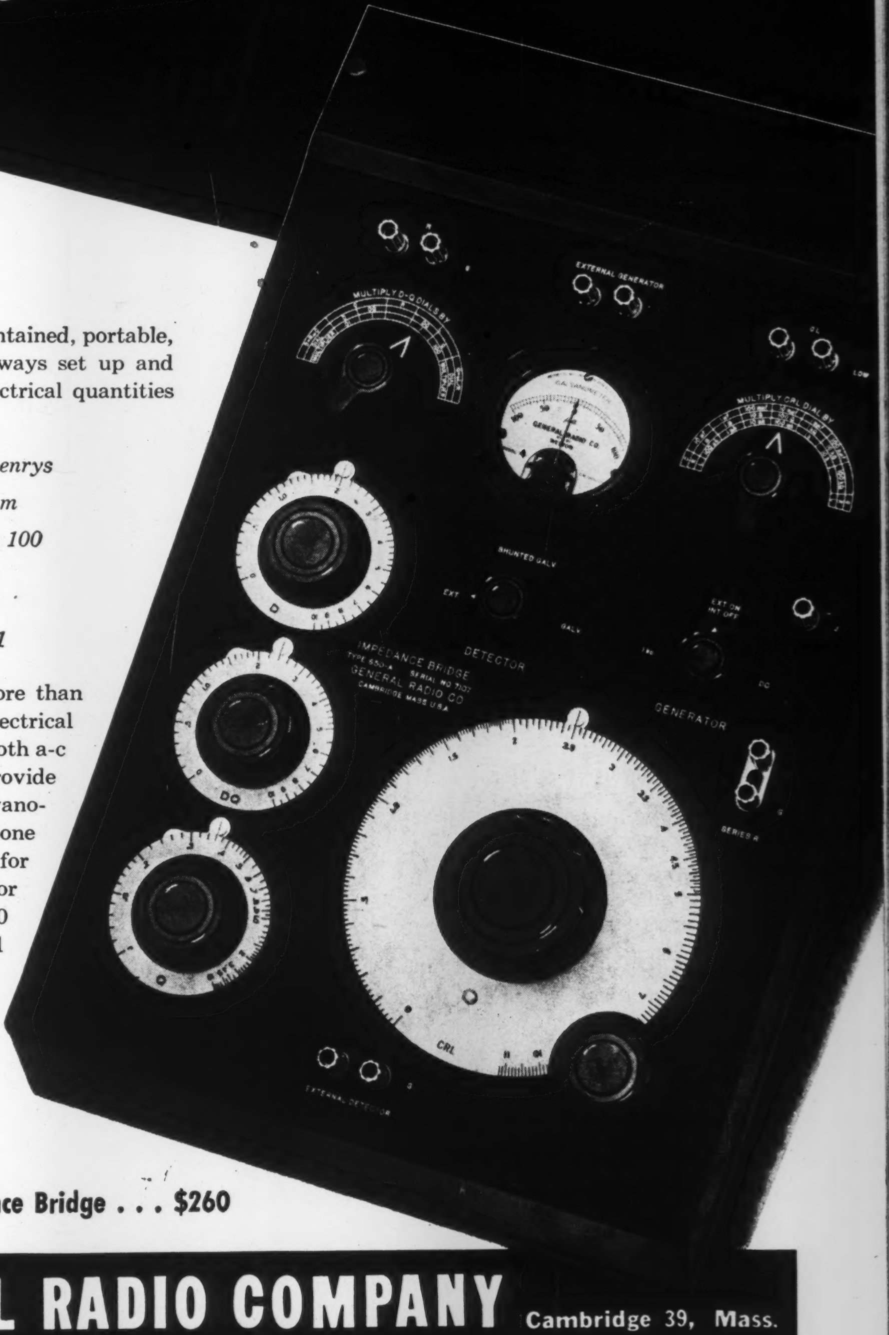




FOR years instrument engineers have tried to build the magnet inside the moving coil for a more compact, more stable, inherently shielded d-c mechanism. In the Model 901 d-c portable instruments, Weston provides a practical and proved design of this type. The Weston core magnet construction gives uniform flux field over a wide deflection angle . . . withstands extreme mechanical abuse . . . and is exceptionally well shielded without increase in size and with a reduction in weight. Be sure to get the details of this remarkable development from your local Weston Representative, or write Weston Electrical Instrument Corporation, 606 Frelinghuysen Avenue, Newark 5, New Jersey . . . manufacturers of Weston and Tagliabue instruments.

WESTON *Instruments*

for Convenient *and* Accurate Measurements


MULTIPLY D-Q DIALS BY
EXTERNAL GENERATOR
GALVANOMETER
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MULTIPLY CRL DIAL BY
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EXT
GALV
DETECTOR
IMPEDANCE BRIDGE
TYPE 650-A SERIAL NO 7107
GENERAL RADIO CO
CAMBRIDGE MASS U.S.A.
GENERATOR
D
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CRL
EXTERNAL DETECTOR

This completely self-contained, portable, lightweight and accurate bridge is always set up and ready to measure these important electrical quantities over very wide ranges:

Inductance: *1 microhenry to 100 henrys*

Resistance: *1 milliohm to 1 megohm*

Capacitance: *1 micromicrofarad to 100 microfarads*

Storage Factor (X/R): *0.02 to 1000*

Dissipation Factor (R/X): *0.002 to 1*

The accuracies obtained are more than sufficient for a large majority of electrical measurements. Provision is made for both a-c and d-c operation. Four dry cells provide the d-c power, with a zero-center galvanometer as the detector; a 1,000-cycle tone source is used for a-c with terminals for headset detection. External generator for measurements from a few cycles to 10 kilocycles can be connected to panel terminals.

Thousands of these bridges are in use in leading laboratories throughout the world. You'll find that once you have used one you can't do without it.

Type 650-A Impedance Bridge . . . $260

GENERAL RADIO COMPANY Cambridge 39, Mass.

920 S. Michigan Ave., Chicago 5 90 West St., New York 6 1000 N. Seward St., Los Angeles 38

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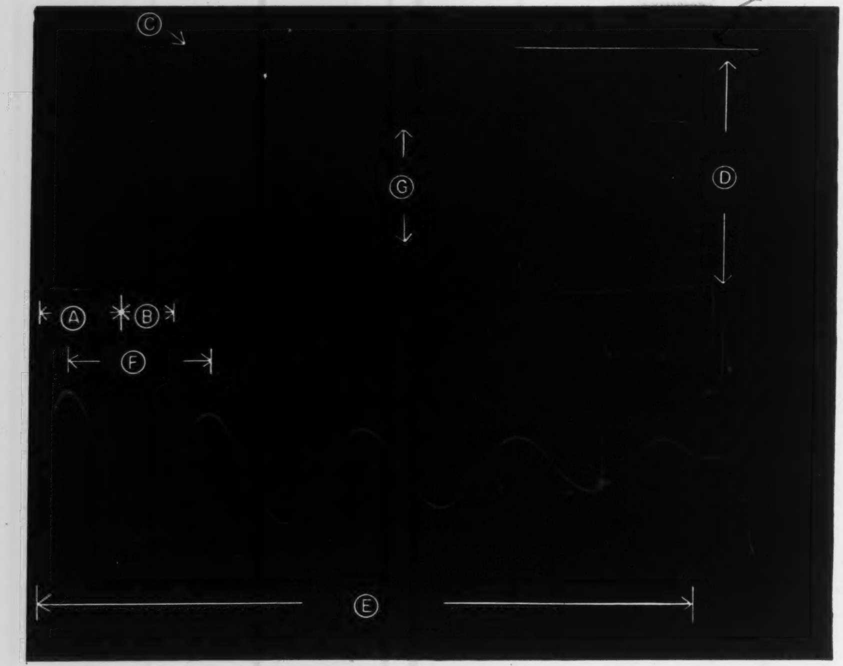

a

SINGLE OSCILLOGRAM demonstrates...

A. Signal Delay
B. Transient Response
C. No High-Frequency Overshoot
D. Undistorted Deflection
E. Sweep Linearity and Speed
F. Time Calibration
G. Amplitude Calibration

Here, woven around the quantitative investigation of a 0.25 microsecond pulse, is a graphic account of the performance features which make the Type 303 an exceptionally fine, high-frequency cathode-ray oscillograph.

...IN THE NEW DU MONT TYPE 303

A. SIGNAL DELAY built into the Y-axis amplifier insures complete display of the steep pulse rise. As illustrated by a portion "A", the 10% point of rise does not occur until sometime after the sweep starts. Y-axis frequency response, of the instrument, includes the performance of the signal-delay line.

B. EXCELLENT TRANSIENT RESPONSE—wholly essential to the proper study of high-speed phenomena—is depicted by the rise time which is reproduced without appreciable degradation. A rise time of 0.01 microsecond, or greater, will be reproduced as a rise time not exceeding 0.03 microsecond.

C. NO OVERSHOOT is observed even on extremely steep wavefronts. The low-frequency response limit is a 3% slope on a 30-cycle squarewave. As shown on the frequency-response curve, there is no positive slope above the mid-frequency range. Since the response tapers off so slowly, the Type 303 is usable at frequencies beyond 10 megacycles. The synchronizing circuits will lock in sine-wave signals as high as 20 megacycles.

D. UNDISTORTED DEFLECTION provided by the Y-axis amplifier is 2.5 inches for unidirectional pulses. An equivalent undistorted deflection of 5 inches is available for symmetrical signals and may be positioned over the useful area of the cathode-ray tube. Even at the highest attenuation ratios, the Y-axis input is not frequency sensitive, as shown by the illustrated pulse which has been attenuated 4000 times. The direct-coupled X-axis amplifier of the Type 303 will provide over 5" of undistorted deflection.

E. SWEEP SPEEDS available in the Type 303 make possible a presentation which is practical for qualitative and quantitative analysis of a pulse as short as 0.25 microsecond. Both driven and recurrent sweeps are continuously variable from 0.1 second to 5 microseconds. Through sweep expansion, sweep length is variable from a fraction of an inch to an effective 30 inches, any portion of which may be positioned on the screen. As shown above, even at the fastest sweep range, the sweep is extremely stable and linear. Notice the absence of jitter.

F. TIME CALIBRATION in the Type 303 is accomplished by substituting a damped sinewave for the signal. Double exposure by photographic recording of calibrating sinewave and signal provides a permanent quantitative analysis of the signal. In addition to the 10-megacycle signal shown above, calibrating frequencies of 10 KC, 100 KC, and 1 MC are also available. Accuracy of time calibration is within 3%.

G. AMPLITUDE CALIBRATION completes the precise, quantitative analysis of the signal. A built-in, regulated, voltage-calibrator provides peak-to-peak signals of 0.1, 1.0, 10, and 100 volts. Similar to time calibration, the amplitude calibrating square wave is substituted for the signal. Amplitude calibration is accurate within 5%.

price $820.00 FOR COMPLETE DETAILS WRITE for bulletin TYPE 303

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VALVE IS YOUR BEST BUY

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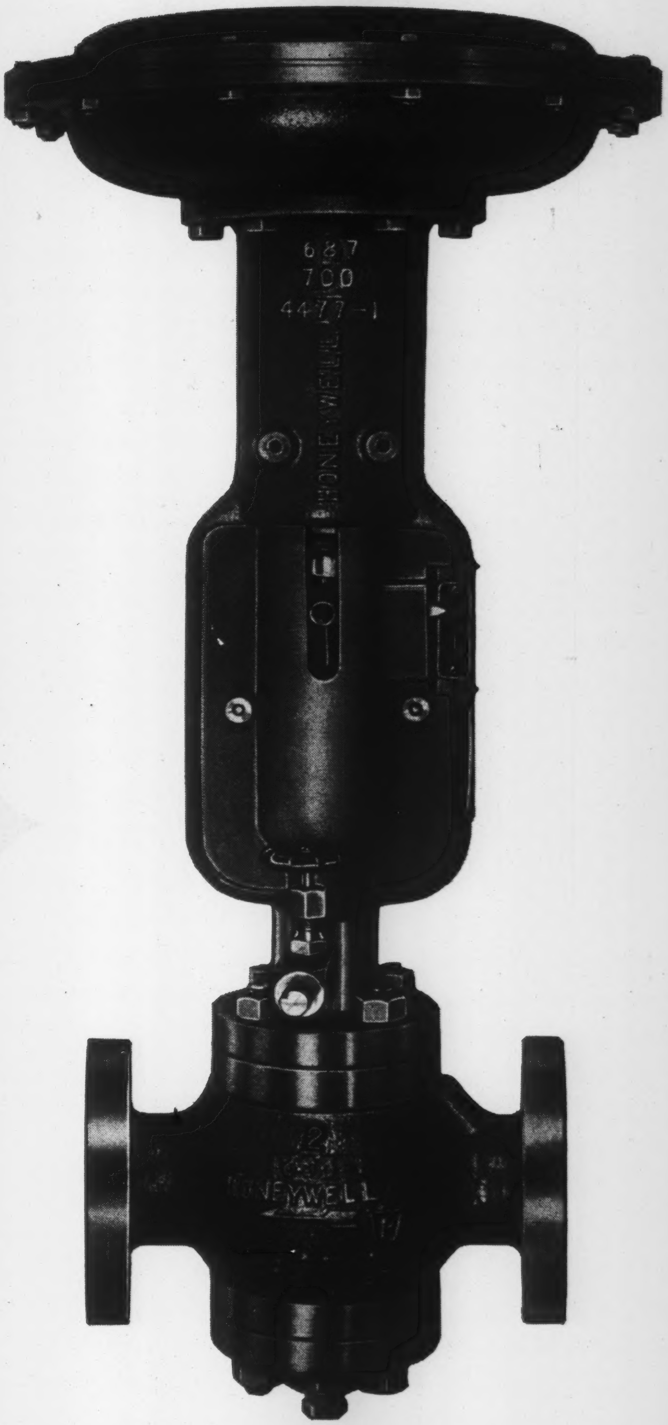
Your comparison will prove that for sensitivity, for dependability, for low maintenance . . . feature by feature, the Honeywell Series 700 is your best buy.

It's available in a wide range of styles and sizes, to suit your specific needs. Write for Specification Sheet 400-3, or call in your local Honeywell engineer . . . he is as near as your phone. MINNEAPOLIS-HONEYWELL REGULATOR CO., *Industrial Division*, 1908 Windrim Ave., Philadelphia 44, Pa. Offices in more than 80 principal cities of the United States, Canada and throughout the world.



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to installation
of instruments
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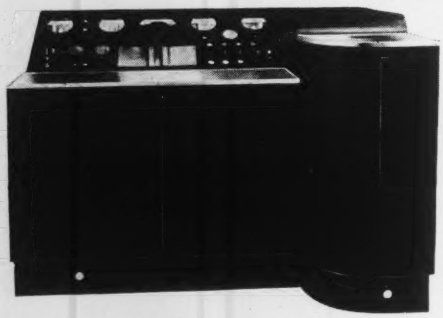

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Instruments

Vol. 24 **JANUARY 1951** No. 1

SPECIAL FEATURE

1950 National Exposition of Power (Pictorial) 45

TECHNICAL ARTICLES

High-speed Direct-trace Recording Methods 30
By Roger Brown Loucks

Standards for Electrical Measurement 35
By Francis B. Silsbee

Power Plant Controls 38
By B. F. Heye

Some Developments in Electronic Instrumentation Including Process Control 42
By W. T. Marchment

THE MONTH'S NEW INSTRUMENTS 60

OTHER REGULAR FEATURES

Editorial 29
Technical Societies 81
Manufacturers' Literature 110
Advertisers' Index 116

JOURNAL of the INSTRUMENT SOCIETY OF AMERICA 91

JOURNAL of the SOUTHERN CALIFORNIA METER ASSOCIATION

Locating Underground Pipes 105
By H. Eggleston

Index to Vol. 23 (1950) 85

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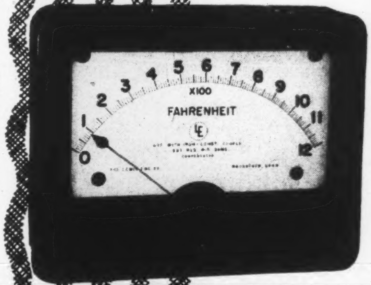
LEWIS INDICATING PYROMETERS

FOR TEMPERATURE TESTING IN THE LABORATORY OR IN THE PLANE . . .

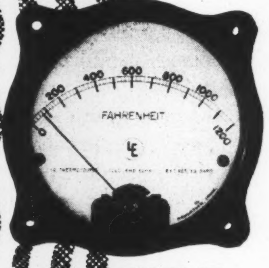
Constructed with the same care as our aircraft temperature indicators, these pyrometers bring "aircraft quality" to the test engineer. Use Lewis leads, thermocouples and selector switches to build complete temperature measuring installations. All models available with black dials and white markings for photographic observers.



MODEL 58PY

This instrument has been used extensively by the leading motor-car manufacturers for road testing on the "Proving Grounds" — where performance counts. Housed in a rectangular bakelite case, this reliable, fully compensated pyrometer is furnished with 6 in. hand drawn scales for greater accuracy. The Model 58PY is available for use with all standard thermocouple materials, in many ranges to suit the most exacting application.

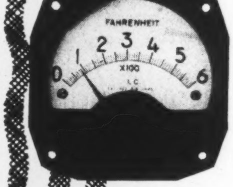
Accuracy — 1% of total scale deflection



MODEL 23B

Manufactured with the same type of movement as our aircraft pyrometers, the Model 23B pyrometer is well suited for use in moving vehicles and has been successfully used in many test stand installations. It is housed in a 4 in. round bakelite case that is flanged for panel mounting, and is available in several ranges for use with various thermocouple materials.

Accuracy — 2% of total scale deflection



MODEL 20B

The Model 20B series of indicators are patterned after our standard aircraft instruments and are supplied with 3" round steel cases suitable for panel installation. These compact, sturdy indicators have 2⅛ in. scales, are fully cold-end compensated and are available in many ranges for use with various thermocouple materials.

Accuracy — 2% of total scale deflection

STANDARD RANGES, ALL MODELS

FAHRENHEIT		*CENTIGRADE*	
0 to 400	0 to 1200	0 to 200	0 to 600
0 to 600	0 to 1600	0 to 300	0 to 800
0 to 800	0 to 1800	0 to 400	0 to 1000
0 to 1000	0 to 2000	0 to 500	0 to 1100
0 to 2500		0 to 1400	

THE LEWIS ENGINEERING CO.

Manufacturers of *Complete* Temperature Measuring Systems for Aircraft

NAUGATUCK, CONNECTICUT

Coordinated

INSTRUMENTATION AND CONTROL by HAGAN

The satisfactory functioning of a system of instrumentation and automatic control requires that the characteristics of each unit of equipment shall be correct for its particular service and that these characteristics shall be coordinated with those of all other related units.

The coordinated equipment developed by Hagan engineers includes pressure measuring and control devices for any range from a few thousandths of an inch water column to 5,000 psig; force measuring devices which will respond to the weight of a dime — or measure the total thrust of a jet bomber; panel type relay units which provide for modification of loadings and for remote manual control; double acting power units in sizes which provide precision control of tiny valves or of heavy slide dampers.

With such a variety of equipment, Hagan engineers can design the system which best meets the requirements of each individual application.

Certain types of installations, for example, are best served by mechanical metering units, with feeler lines connected direct to a self-contained recorder. The Hagan Ring Balance Flow Meter is designed particularly for this type of service.

Standard assemblies are made to measure flow differentials from ½ inch up to 420 inches WC, at static pressures as high as 15,000 psig.

These units may indicate, record and integrate one or two rates of flow. Addition, subtraction and compensation for temperature and pressure conditions may be included. Integration is maintained with high accuracy, even at the lowest flow rates.

Other types of installations may require that measuring elements be located near the primary device, sending pneumatic signals to recorders, as well as to control circuits. For this service, the Ring Balance Transmitter may be used at static pressures up to 15,000 psig and measuring maximum differentials as high as 420 inches WC.

Other types of units for translating pressure differentials into pneumatic signals are designed to serve as line type liquid meters or as differential measuring units in various ranges to a maximum pressure differential of 100 psi at static pressures up to 1,500 psig.

In all except the very simplest control systems, there is specific need for control mechanisms which can combine control signals. Some involve addition or subtraction of signals, while others involve multiplication, division, or even more complicated functions. The Hagan Ratio Totalizer is designed for almost universal application for accurately combining input control pressures and spring forces to produce a single pneumatic output control signal.

The Hagan THRUSTORQ, for translating mechanical forces into pneumatic signals for instrument or control circuits, fulfills the exacting requirements of aeronautical and similar testing laboratories.

Other Hagan Automatic Control units are designed for measurement and control of pressure, draft, temperature, engine or turbine speed, fuel-air ratio, damper or valve positioning, and the many other functions which may enter into the final solution of a particular problem.

A letter or a telephone call to the nearest office will enlist at once the coordinated facilities of our engineers in solving *your* problem.

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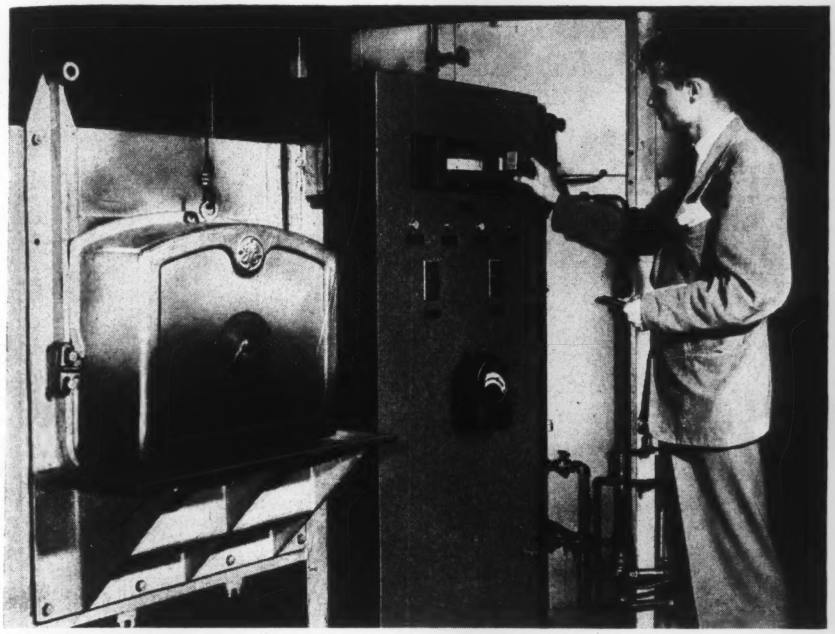


This General Electric Type HP-3 Pyrometer controls a ribbon-resistor box furnace.

PYROMETER EQUIPMENT

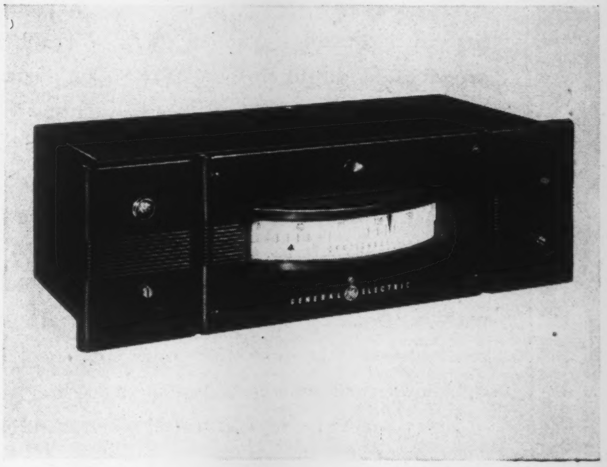
With the introduction of this completely new line of Pyrometer Equipment, General Electric offers you accurate indication and temperature control of furnaces, ovens, kilns, and other industrial-heating equipment.

ACCURATE INDICATION. Calibrated accuracy is within ¾ of 1 per cent of full scale. Automatic cold-junction compensation assures that changes in ambient temperature will not appreciably affect accuracy.

CLOSE TEMPERATURE CONTROL. Any change in temperature equivalent to 1/10 of 1 per cent of full scale starts immediate control action. Normal changes in humidity, ambient temperature, and voltage have little or no effect on the exactness of control action.

DEPENDABLE OPERATION. Substantial industrial components and strong construction throughout make G-E pyrometers exceptionally rugged. A 3¼-pound alnico magnet provides high flux density and allows large air gaps; lightweight moving system has high resistance to shock and vibration.

For more details, get in touch with your nearest General Electric representative, or write for Bulletin GEA-5534, "G-E Pyrometer Equipment." Apparatus Dept., General Electric Company, Schenectady, N. Y.



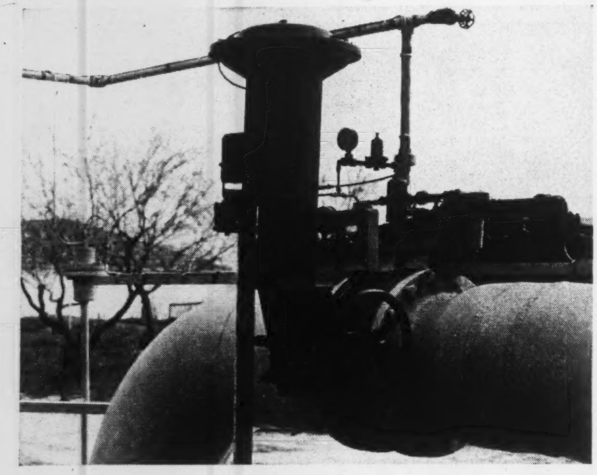
General Electric's pyrometer line consists of flush- or surface-mounted indicators, controllers and protectors. Shown above is Type HP-3 two-position indicating controller. A three-position controller is also available.

GENERAL ELECTRIC

602-198

R-S valvEvents

• EXCERPTS FROM THE R-S BOOK OF EXPERIENCE •



Minimum Pressure Drop

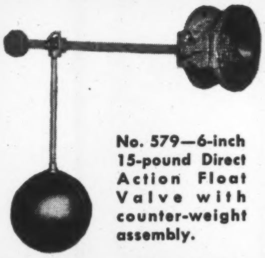
SAVES POWER

The beveled vane of an R-S Valve seats firmly against the valve body to produce commercially tight shut-off with metal-to-metal seat. A rubber seat produces drip-tight closure. In the open position the streamlined vane creates a Venturi action. Pressure drop in R-S Valves is low, and they therefore produce substantial savings in pumping costs.

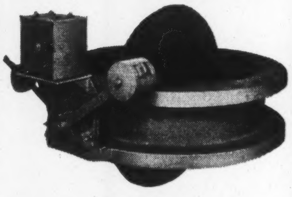
Illustration shows a heavy duty R-S Valve used in the water system to a compressor house. Valve is equipped with diaphragm motor, handwheel control with self-locking worm and gear and declutching mechanism together with outboard bearing for operating shaft with goose neck support.

Every R-S Valve is engineered and constructed for rugged service and provided with such safety factors that it will give complete satisfaction in the service for which it is designed. Consult with your local R-S Valve Engineers or write direct.

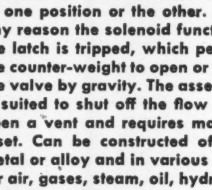
R-S PRODUCTS CORPORATION
4600 Germantown Avenue
Philadelphia 44, Pa.



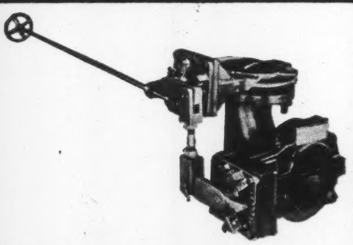
No. 579—6-inch 15-pound Direct Action Float Valve with counter-weight assembly.



No. 628—Solenoid Trip Valve is used for emergency service. The solenoid can be arranged with the counter-weight mechanism to open or close the valve and hold it there in one position or the other. If for any reason the solenoid functions, the latch is tripped, which permits the counter-weight to open or close the valve by gravity. The assembly is suited to shut off the flow or to open a vent and requires manual reset. Can be constructed of any metal or alloy and in various sizes for air, gases, steam, oil, hydraulic and other services.



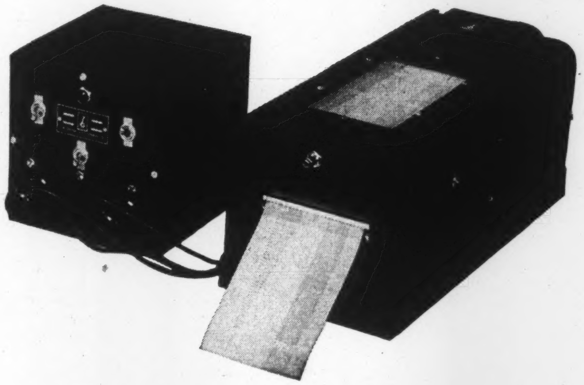
No. 677—1500-pound Welding End Steel Valve for superheated steam service. A.S.M.E. standards with heavy duty handwheel control.



No. 795—Three-inch 3-way Valve Type No. 733 utilizing standard tee and two wafer valves with extended handwheel control.

Simplify analysis

WITH THESE *Brush* INSTRUMENTS



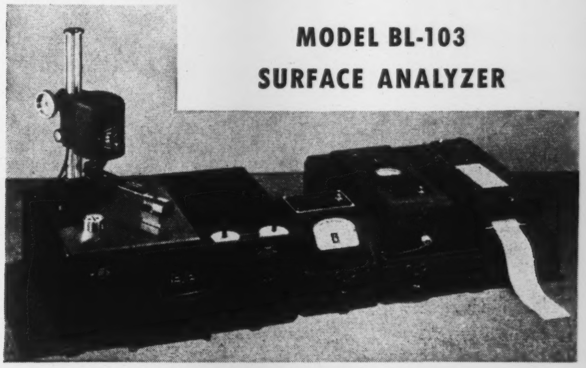
COMBINATION MAGNETIC OSCILLOGRAPH

The Model BL-221 Single Channel Magnetic Combination Oscillograph is similar to the Model BL-201 unit, except that circuit changes have been made to permit use of either a standard inking pen or an electric stylus. Magnetic penmotor Model BL-943 is used on the BL-221 Oscillograph and includes the proper connections for use of the electric stylus. A Power Supply, Model BL-944, furnishes voltage for the electric stylus operation. A switch on the front panel of the Power Supply permits the operator to increase the stylus voltage when recording high frequency phenomena. The main switch opens circuit to Power Supply to eliminate the possibility of receiving electric shock when handling stylus. Instruments are supplied with a standard pen and inkwell as well as the electric stylus. The Model BL-222 Double Channel Oscillograph (shown in illustration) is supplied on the same chassis as the BL-221.

BL-932 D-C AMPLIFIER

Designed for use with the Brush Magnetic Direct Inking Oscillograph, and used to make recordings of many types of phenomena heretofore measured only with the aid of complicated intermediate equipment. Studies of such static or dynamic conditions as strains, displacements, pressures, light intensities, temperatures, d-c and a-c voltages or currents, and many others, are simplified by the use of the Brush Direct Inking Oscillograph with the BL-932 Amplifier. Voltage gain is sufficient to give one chart mm deflection per millivolt input. Novel design features reduce the effects of power line fluctuation. Zero signal drift amounts to not more than one chart mm per hour. Frequency response is essentially uniform from d-c to 100 cycles per second. The control panel at the front of the amplifier contains a factor-of-10 attenuator, gain control, calibrating meter, and controls for determining input voltages. A balancing potentiometer is provided for electrically biasing the oscillograph pen to any position on the chart.

MODEL BL-103 SURFACE ANALYZER



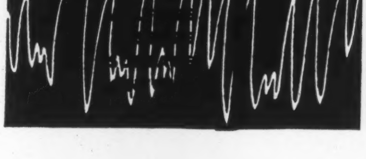
For exploration and instantaneous charting of surface finishes—metals, glass, plastics, paper, plated and painted surfaces from less than 1 to 5000 microinches. Complete with PA-2 Pickup Arm, Drive Head, Amplifier, Magnetic Oscillograph, Surface Plate, Carrying Cases, Glass Calibration Standard, 2 V-Blocks, 6 rolls Chart Paper, one 2 oz. bottle Red Ink, connecting cords and operating instructions. Brush RMS METER: "average reading" type calibrated in terms of the "RMS" of an equivalent sine wave. It provides a constant visual check of "RMS" surface roughness in cases where "hill and dale" chart profiles are not needed. Large illuminated dial is set at an easy reading angle. "RMS" Meter may be purchased separately or with the Surface Analyzer.

UNIVERSAL STRAIN ANALYZER

The BL-320 Universal Strain Analyzer, when used with the Brush Magnetic Direct Inking Oscillograph, provides a complete package unit for the measurement of strain or other phenomenon where a resistance sensitive pickup is employed. It can be simply operated, producing records which are immediately available and easily interpreted. This combination equipment records either static or dynamic strains up to 100 cps, and direction as well as magnitude of the measured strain can be read from the chart. Connections are brought out so that one to four active gages may be used. Provision is made for connecting an internal calibrating resistor in the bridge circuit and adjusting the overall gain.

Write for complete details.

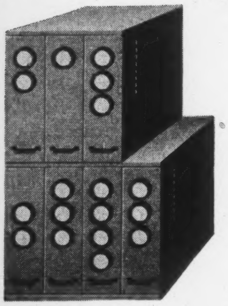
THE *Brush* DEVELOPMENT COMPANY
DEPT. A-1, 3405 PERKINS AVENUE • CLEVELAND 14, OHIO, U. S. A.
Canadian Representatives:
A. C. Wickman (Canada) Limited, P. O. Box 9, Station N, Toronto 14, Ontario



it in writing with a

BRUSH RECORDING ANALYZER

STRAIN ANALYZERS • SURFACE ANALYZERS • CONTOUR ANALYZERS • UNIVERSAL ANALYZERS • UNIFORMITY ANALYZERS



no hand controls this "brain"

Look for amazing things to come from the engineers who designed it

It's an Analogue Computer, contract developed and manufactured by Arma Corporation for the Armed Forces. The human element enters not at all into its continuous solution of many complex equations simultaneously and the deadly accuracy with which it controls the fire of shells and other missiles. It translates original data into required results automatically . . . is the swiftest means of computing problems in which factors vary continuously.

Symbolizing the engineering progress crowded into the post-war years at Arma, the modern electrical analogue computer is composed of interchangeable Arma "Brain Blocks"*. Highly trained technical personnel is not required to service it.

The Analogue Computer is an example of the complex types of instrumentation Arma has developed and manufactured. Other amazing things developed by Arma engineers include many combinations of computer elements and servo mechanisms that advance the automation of industry. The only limits to automation recognized at Arma are situations defying reduction to finite mathematical formulae.

Arma Corporation has devoted more than 30 years to contract development and manufacture of unique things.

***"Brain Block" components and the "Brain Block" technique of instrumentation were created by the people of Arma Corporation. The contributions thus made to the development of electrical brains for machines stagger the imagination.**

ARMA CORPORATION
254 36th STREET, BROOKLYN 32, N. Y.
SUBSIDIARY OF AMERICAN BOSCH CORPORATION

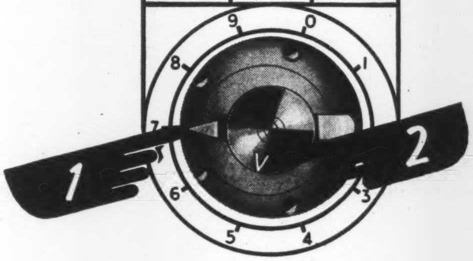
ARMA PRODUCTS RELEASED FOR PRIVATE INDUSTRY

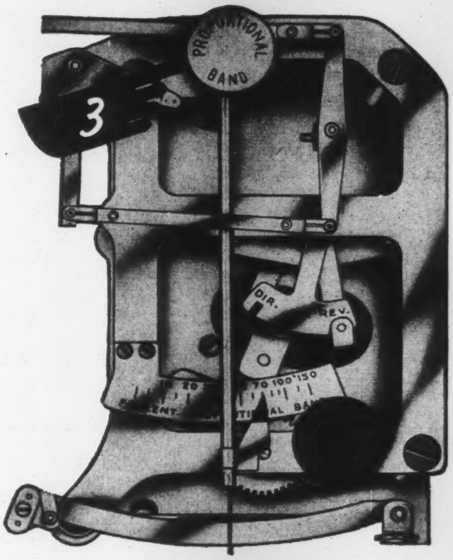
ARMA ELECTRICAL RESOLVERS* • ARMA SYNCHROS • ARMA INDUCTION MOTORS • ARMA INDUCTION GENERATORS • ARMA MECHANICAL DIFFERENTIALS • ARMA ALTERNATING VOLTAGE COMPARATOR • COMPUTING MECHANISMS • INDUSTRIAL CONTROLS • STABILIZATION DEVICES • NAVIGATIONAL EQUIPMENT • LIMITRON AUTOMATIC INSPECTION SYSTEM

*Licensed for use under Arma patents Nos. 2,465,624 and 2,467,646. License information available.

QUALITY ARMA INSTRUMENT PRECISION

DERIVATIVE TIME	SCALE SETTING	RESET RATE
0	0	0
.1	1	.03
.15	2	.05
.25	3	.08
.40	4	.12
.75	5	.18
1.20	6	.25
2.00	7	.35
3.00	8	.50
5.00	9	.75





if you use . . . or plan to use . . . automatic control instruments

you should investigate

these **THREE EXCLUSIVE ADVANTAGES** you get in

BRISTOL series 500 air-operated controllers

1. Reset Rate . . .
2. Derivative Time . . .
3. Proportional Band . . .

ACCURATELY CALIBRATED AND EXACTLY REPRODUCIBLE

The reset scale is calibrated in actual reset rate. The proportional band scale is graduated in percent of proportional band. The derivative scale is calibrated directly in minutes.

This makes possible the exact duplication of controller adjustments for any process throughout a national organization.

It also makes possible the replacement of controllers on a process with full assurance that such replacements will exactly duplicate the performance of the original—eliminates the cut-and-try method of arriving at the original setting—saves hours by cutting down on shut-down time.

Accurate reproducibility is only one of the many advantages you get in Series 500 Air-Operated Controllers which exemplifies the outstanding instrument engineering Bristol puts into its complete new line of Series 500 recording and controlling instruments—products of over 60 years of instrument experience.

Write for new Bulletin A120 on Series 500 Air-Operated Controllers. THE BRISTOL COMPANY, Bristol Road, Waterbury 20, Conn.

BRISTOL

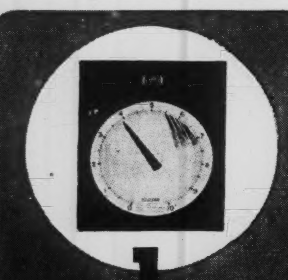
Engineers process control for better products and profits

AUTOMATIC CONTROLLING, RECORDING AND TELEMETERING INSTRUMENTS

4 ways to know your combustion efficiency

The ever-increasing pressure for fuel economy makes some type of "combustion guide" instrument an essential part of any modern fuel burning operation. Hays offers the most complete line of such instruments in the industry—adaptable to your cost and engineering requirements. Your particular needs with regard to price, accuracy, speed of response, etc., will determine your choice—*however, whatever your needs, Hays has the instrument.*

Select your combustion guides *from the most complete line in the industry*



1

HAYS MAGNOTHERM O_2 METER

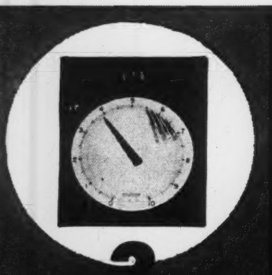
Measures fundamental indicator of combustion efficiency —Oxygen. Electronic in operation, with all of the most advanced features incorporated into its design, it is applicable not only to power plant conditions but also to a host of process problems such as catalytic crackers, open hearths, process heaters, inert gases, etc.

PRINCIPLE

Based on paramagnetic (attracted by magnetism) properties of oxygen. All other gases usually encountered are slightly diamagnetic (repelled by magnetism).

FEATURES

- Highly sensitive to change in O_2 content
- Rapid response to change in O_2 content
- Electrically operated
- Electronic type recorder
- Temperature controlled
- Pressure compensated
- No liquid or gaseous fuel required to be added
- No chemicals
- High accuracy maintained
- Not affected by wide change of gas flow rate
- Continuous sampling and recording
- Glass and corrosive resistant sampling system
- Remote mounted analyzer
- Remote mounted recorder
- 12" 24-hour chart
- O_2 recorder and indicator
- 4 records on same chart possible
- Low maintenance



2

HAYS CONDU-THERM CO_2 METER

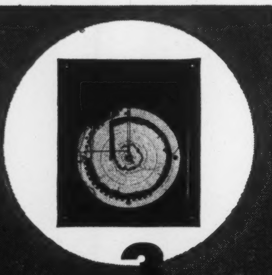
Meter incorporates all of the construction and manufacturing ideas which Hays has developed during many years of experience in gas analysis. A deluxe instrument, the Condu-Therm CO_2 Analyzer is especially applicable to the larger boiler plants and to industrial processes.

PRINCIPLE

The principle of operation used in the Hays Condu-Therm Meter is that of thermal conductivity of gases, i.e., that all gases conduct heat at different rates.

FEATURES

- Electrically operated
- Electronic type recorder
- Temperature controlled
- Humidity controlled
- No chemicals required
- No moving parts in analyzer
- Continuous sampling
- No drying agent required
- Easily installed glass and corrosion resisting sampling system
- Not affected by wide change in gas flow rate
- Rapid response
- High sensitivity
- Continuous recording
- Remote mounted analyzer
- Remote mounted recorder
- 12" 24-hour chart
- CO_2 Recorder and Indicator
- As many as 4 records on same chart
- Low maintenance



3

HAYS COMBUSTION METER

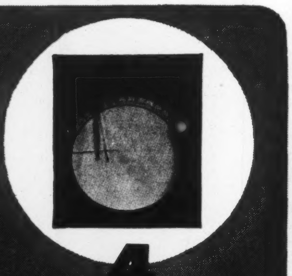
Hundreds of these meters have been in operation for many years in all types of plants burning all kinds of fuels and saving thousands of fuel dollars.

PRINCIPLE

Operates on Orsat principle of Volumetric measurement and chemical absorption. Extremely simple: sample of flue gas trapped and accurately measured; passed through chemical which removes CO_2 component of gas mixture. Sample is re-measured, volume compared to original sample. Difference before and after absorption gives exact percentage of CO_2 absorbed by chemical.

FEATURES

- Low price
- Water operation
- Pressure and temp. compensated
- Volumetric determination
- Chemical absorption
- 2 minute operating cycle
- Easily understood
- Rugged construction
- Low maintenance
- Available in 6 remote mounted types and 3 integral types
- Remote or integral mounting
- 10" 24-hour chart
- Available for: (a) CO_2 only—recording with or without indicator (b) CO_2 and flue gas temperature recorder combined (c) CO_2, draft or flue gas temperature recorder combined



4

HAYS-PENN BOILER EFFICIENCY METER

Provides a QUANTITATIVE guide to efficiency — deals with quantities of air and steam; by contrast CO_2 and O_2 meters are QUALITATIVE guides since they determine directly quality of combustion gases. Both Boiler Efficiency Meter and Gas Analysis Meter are used to obtain advantages of both methods.

PRINCIPLE

Pounds of air required to burn each pound of coal vary widely with heating value of coal; constant weight of air is required to produce same Btu. Similar relationship exists when oil and natural gas are used as fuels. Record of steam flow is assumed to be Btu's produced; record of air flow is calibrated to flow of air required to generate that steam.

FEATURES

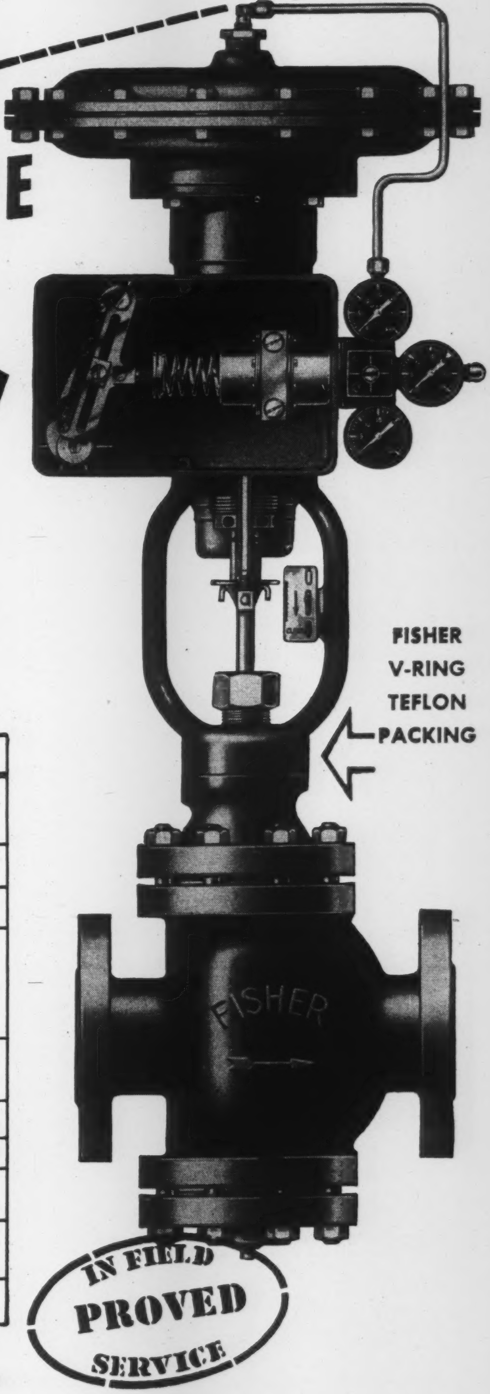
- Electric operation of flow meter and air flow recorder
- Diaphragm type air flow measuring unit
- Air flow measuring element does no work
- Air flow recorder—motor operated
- Adjustable cam air flow calibration
- Mercury transmitter—pressures to 2500 psi
- Interchangeable range tubes for steam flow
- Remote mounted steam flow transmitter
- No high pressure piping into panel
- Easily installed and adjusted
- Low maintenance

THE **HAYS** CORPORATION
MICHIGAN CITY 8, INDIANA

Automatic Combustion Control • Boiler Panels • Hays-Penn Flowmeters
Veriflow Meters and Veritrol • Gas Analyzers • Draft Gages
Combustion Test Sets • CO_2 Recorders • Electronic Oxygen Recorders

FISHER® POSITROL

FOR ACCURATE POSITIVE VALVE POSITIONING



Features

- COMPACT — SIMPLE RUGGED
- 2 YEARS FIELD SERVICE
- EASILY ADJUSTABLE
- FORCE BALANCE TYPE OF POSITIONER
- AVAILABLE WITH OR WITHOUT BY-PASS
- USABLE AS REMOTE POSITION INDICATOR
- FOR DIRECT OR REVERSE ACTION VALVES

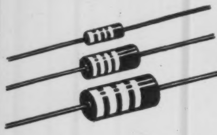
Technical Data

TEST			FISHER TYPE 3500
INSTRUMENT PRESSURE SENSITIVITY CONTROLLING PRESSURE CHANGE NEEDED TO PRODUCE 2 LBS. TO 15 LBS. TO DIAPHRAGM			0.07 LB.
STEM MOVEMENT SENSITIVITY AMOUNT STEM CHANGE TO PRODUCE 2 LBS. TO 15 LBS. TO DIAPHRAGM	½" TRAVEL		0.0037" AVE.
	2" TRAVEL		0.015" AVE.
SPEED TIME IN SECONDS FOR FULL TRAVEL	SIZE	TRAVEL	
	DD	¾"	1.2 — 1.2 SEC.
	FF	1½"	4.2 TO 4.8 SEC.
	GG	2"	7.2 SPC TO 9.6 SEC.
	HH	2"	10.5 TO 12.6 SEC.
LAG ERROR IN POSITION AT 9 LBS. CONTROLLER PRESSURE	½" TRAVEL		0.0006" AVE.
	2" TRAVEL		0.001" AVE.
EFFECT OF VARIATIONS IN AIR SUPPLY PRESSURE	½" TRAVEL		0.1 LB. PER 5 LB. CHANGE
	2" TRAVEL		0.1 LB. PER 5 LB. CHANGE
CHARACTERISTICS CONTROLLED P VS DIAPHRAGM P			LINEAR
COMMENTS			STABLE ADJUSTMENTS ALL EASY AND SIMPLE
AIR CONSUMPTION NORMAL 9 LBS. DIAPHRAGM PRESSURE			15.0 CU FT/HR

IN FIELD
PROVED
SERVICE

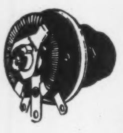
FOR COMPLETE DETAILS WRITE FOR BULLETIN E-3500.

Fisher Governor Co., **Marshalltown, Iowa**



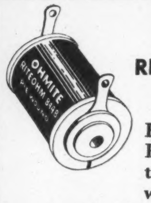
LITTLE DEVIL COMPOSITION RESISTORS

Resistance and wattage are clearly marked on every one of these tiny, rugged insulated composition resistors. Three sizes: ½, 1 and 2-watt in all RMA resistances. Tolerance ±5% and ±10%.



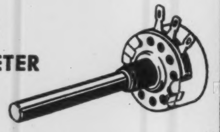
CLOSE CONTROL RHEOSTATS

Insure permanently smooth, close control. Widely used in industry. All ceramic, vitreous enameled; 25, 50, 75, 100, 150, 225, 300, 500, 750, and 1000-watt sizes.



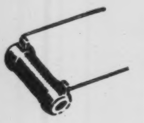
RITEOHM PRECISION RESISTORS

For critical applications. Extremely accurate—1% tolerance, in ½- and 1-watt sizes and a wide range of values. Pie-wound non-inductive, and single-layer wound units. Lug, screw, or wire mounting.



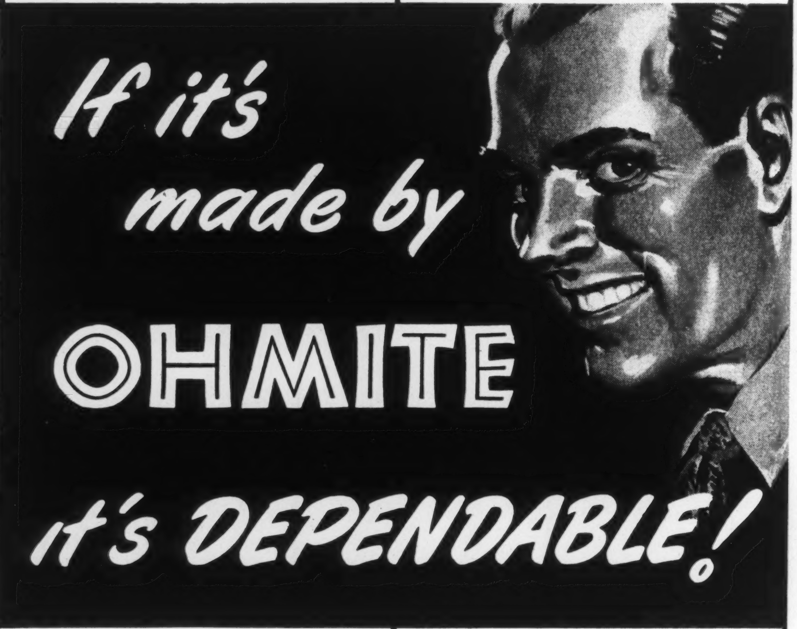
TYPE AB POTENTIOMETER

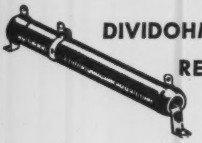
It's quiet! This Type AB Potentiometer has a resistance unit that's solid molded. As a result, the noise level often becomes less with use. Has a 2-watt rating, good safety factor.



BROWN DEVIL WIREWOUND RESISTORS

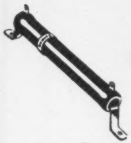
Dependable vitreous-enameled units, in a size small enough to fit most installations. Easily mounted by 1½" tinned wire leads. Three sizes: 5, 10, and 20 watts. Tolerance ±10%.





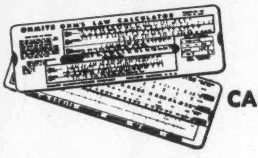
DIVIDOHM ADJUSTABLE RESISTORS

These wirewound resistors, with one or more adjustable lugs, provide a convenient means of obtaining odd resistance values. Stock units made in 10, 25, 50, 75, 100, 160, and 200-watt sizes, in many resistance values.



FIXED RESISTORS

Resistance wire is wound over a ceramic core, permanently locked in place, insulated and protected by Ohmite vitreous enamel. In 25, 50, 100, 160, and 200-watt stock sizes; values from 1 to 250,000 ohms.



OHM'S LAW CALCULATOR

25¢

Favorite of engineers everywhere! Solves Ohm's Law problems with one setting of the slide. Also has parallel resistance and slide rule scales.

To countless thousands of technical men all over the world—engineers, designers, and servicemen—the name OHMITE has become synonymous with *dependability*. There is good reason for this overwhelming opinion. Every OHMITE product is carefully designed and constructed to give *extra* performance and long life under severe service conditions. When you need dependable resistance components, play safe and specify OHMITE.

Write
on Company letterhead for CATALOG 40

OHMITE MANUFACTURING CO., 4886 Flournoy St., Chicago 44, Ill.

***Be Right with* OHMITE®**

RHEOSTATS
RESISTORS
TAP SWITCHES

WONDER WORKERS... that may help you!

IT SEEMS there's no limit to what Sylphon bellows assemblies and bellows devices can do—whenever there's a design problem involving control of temperatures or pressures.

For these wonder workers (a few are pictured above) are used in hundreds of ways. They open and close valves, dampers, etc., absorb expansion, provide packless construction—have many more useful applications.

But designing and producing them calls for specialists. That's where Fulton Sylphon and Bridgeport Thermostat *complete* the picture. When you call upon them, you get the unique advantages of nearly half-a-century of experience in this specialized field.

You get more, too. Skilled personnel—careful workmanship—the kind of service that meets your production schedules. Costwise, that can mean important savings for you.

We may have a ready-made control that will fit your product or product plans. If not, we'll work with you to develop and produce bellows assemblies and bellows devices that are *exactly* what you require. Wide range of metals and sizes—ample production facilities. Send for idea-filled catalog AE-1200.

TEMPERATURE CONTROLS

FULTON SYLPHON
DIVISION
Knoxville 4, Tenn.

Robertshaw-Fulton
CONTROLS COMPANY

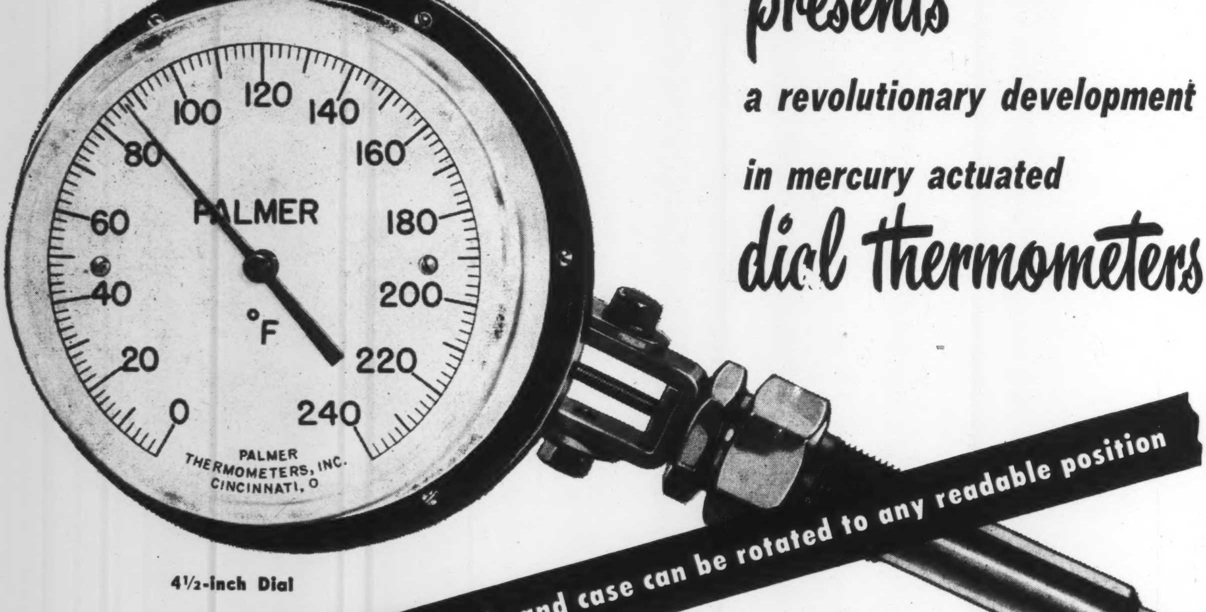
BRIDGEPORT THERMOSTAT
DIVISION
Bridgeport 1, Conn.

BELLOWS ASSEMBLIES • BELLOWS DEVICES

PALMER a great name in thermometers

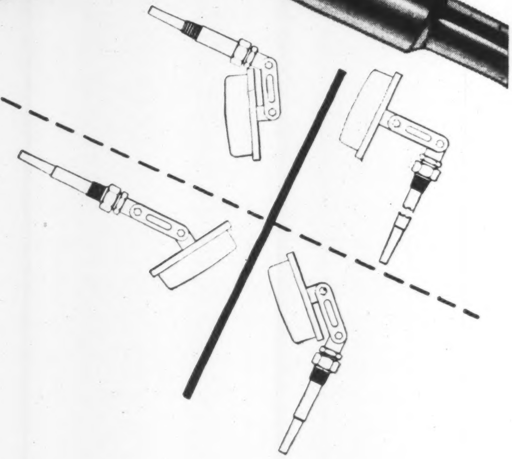
presents

a revolutionary development in mercury actuated dial thermometers



4½-inch Dial

Stem can be placed at any angle and case can be rotated to any readable position



for accuracy:
Mercury actuated . . . Fully Compensated by Invar Compensation. Guaranteed Accurate 1 scale division.

for readability:
Bold Black Numbers . . . 11" of scale Reading Dial face can always be placed in easiest readable position.

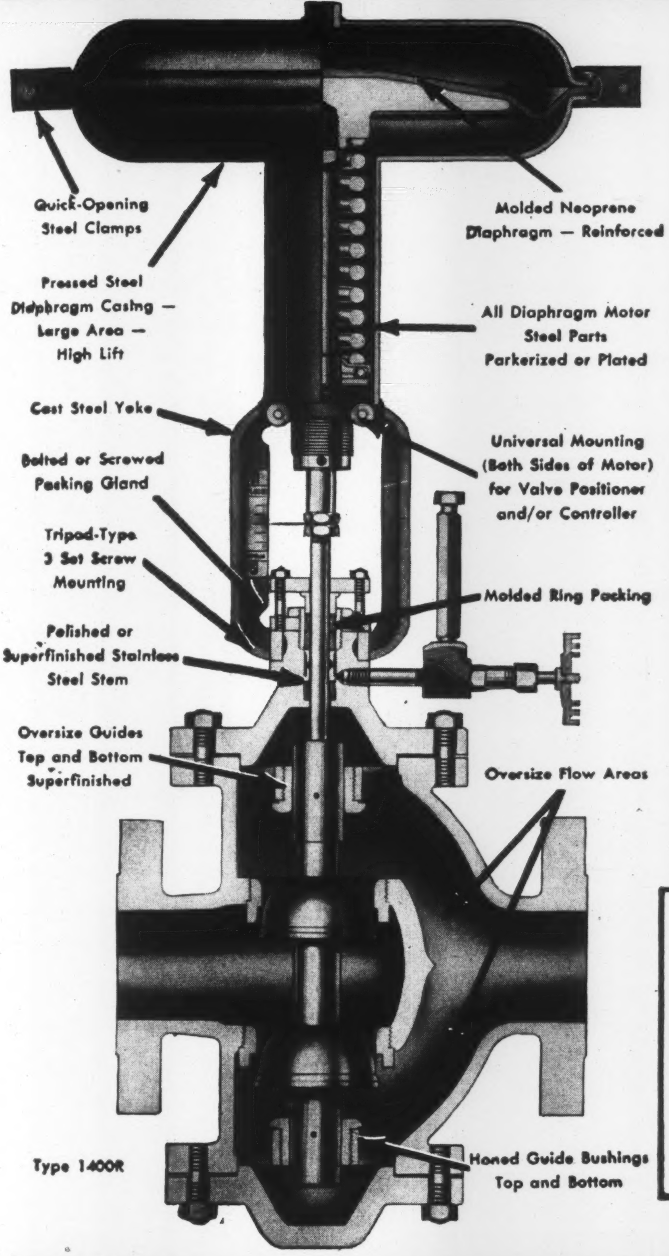
for angularity:
Can be adjusted to most readable position at any angle desired.

for interchangeability:
Always specify "PALMER" Separable sockets as they are interchangeable for Dial or Industrial type Thermometers.

SEND FOR THIS BULLETIN
For details on the new Palmer Dial Thermometer please write for Palmer Bulletin 50-128.

PALMER THERMOMETERS, INC.
Mfrs. of Industrial Laboratory, Recording and Dial Thermometers
2511 NORWOOD AVE., CINCINNATI 12, O.

ADVANCED-TYPE VALVE FOR EXACTING CONTROL



Quick-Opening Steel Clamps
Pressed Steel Diaphragm Casing — Large Area — High Lift
Cast Steel Yoke
Bolted or Screwed Packing Gland
Tripod-Type 3 Set Screw Mounting
Polished or Superfinished Stainless Steel Stem
Oversize Guides Top and Bottom Superfinished
Type 1400R
Molded Neoprene Diaphragm — Reinforced
All Diaphragm Motor Steel Parts Parkerized or Plated
Universal Mounting (Both Sides of Motor) for Valve Positioner and/or Controller
Molded Ring Packing
Oversize Flow Areas
Honed Guide Bushings Top and Bottom

K & M Diaphragm Control Valves embody the accessibility and other desirable features of the "open yoke", formerly available only in cast iron construction, together with the strength and resistance to shock found only in steel.

The diaphragm casing assembly is the exclusive K & M Boltless Duoseal design which allows quick disassembly. The large diaphragm is molded so there is full effective contact with the diaphragm button during the complete valve stroke. This construction, together with heavy, calibrated, long-travel springs gives an unusually high power factor for extremely precise control.

Flow passages of the valve body have a minimum average area of 140% of comparable size pipe area; inner valve open free areas average 80% of pipe area. This design permits pressure drop to take place principally through the inner valve, assuring complete control over the full valve stroke.

Send for K & M Bulletin S10 for details and data.

K&M SERIES 1200 and 1400

Available sizes — ½ to 16 inches.

Construction — Cast iron, carbon and stainless steels and most machineable alloys.

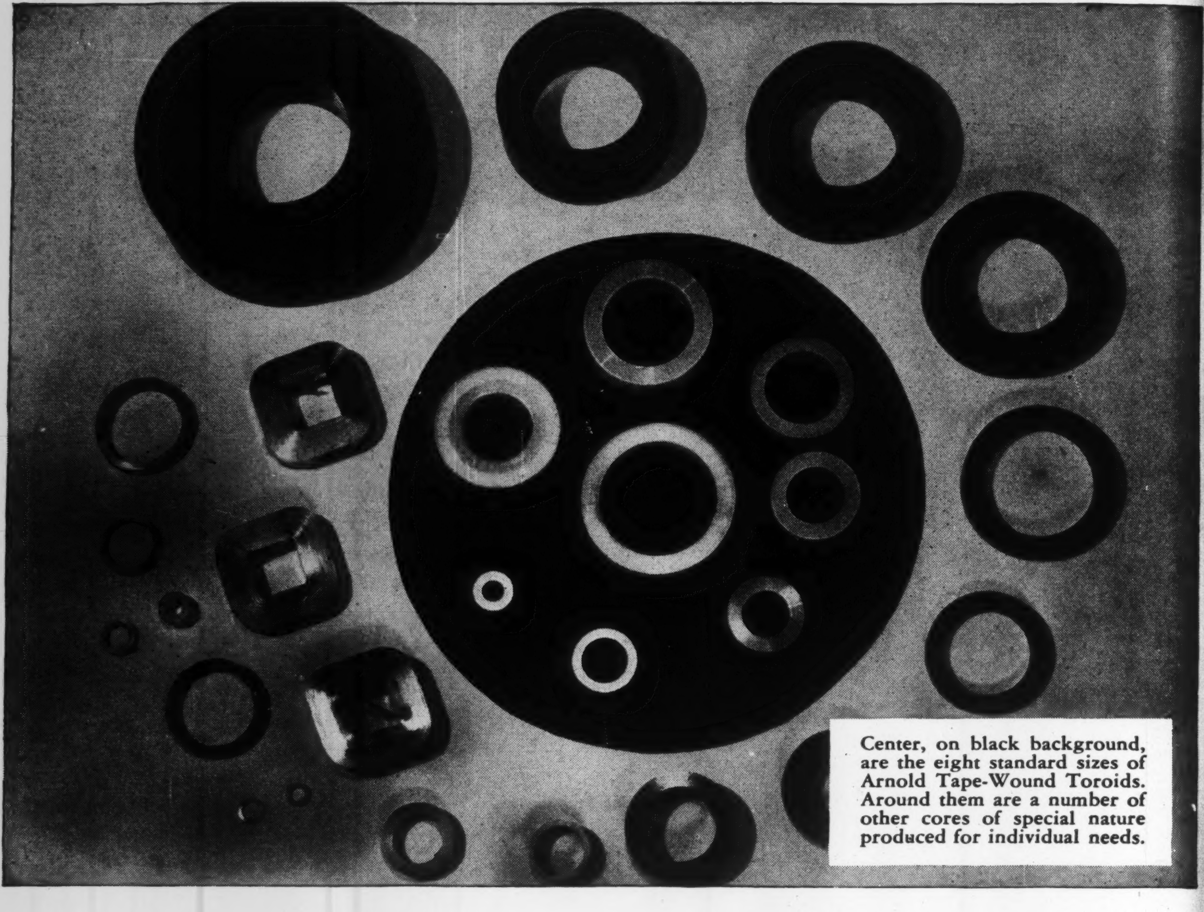
Inner Valves — A wide range of styles and characteristics to meet varying requirements.

Action — Designed for direct or reverse action.

KIELEY & MUELLER

Established 1879

2033 - 43rd STREET NORTH BERGEN, N. J.



Center, on black background, are the eight standard sizes of Arnold Tape-Wound Toroids. Around them are a number of other cores of special nature produced for individual needs.

ARNOLD TAPE-WOUND TOROIDAL CORES

of DELTAMAX 4-79 MO-PERMALLOY SUPERMALLOY*

APPLICATIONS

MAGNETIC AMPLIFIERS
PULSE TRANSFORMERS
NON-LINEAR RETARD COILS and TRANSFORMERS
PEAKING STRIPS, and many other specialized applications.

RANGE OF SIZES

Arnold Tape-Wound Toroids are available in eight sizes of standard cores—all furnished encased in molded nylon containers, and ranging in size from ½" to 2½" I.D., ¾" to 3" O.D., and ⅛" to ½" high.

RANGE OF TYPES

These standard core sizes are available in each of the three magnetic materials named, made from either .004", .002" or .001" tape, as required.

In addition to the standard toroids described at left, Arnold Tape-Wound Cores are available in special sizes manufactured to meet your requirements—toroidal, rectangular or square. Toroidal cores are supplied in protective cases.

**Manufactured under licensing arrangements with Western Electric Company.*

W&D 3182

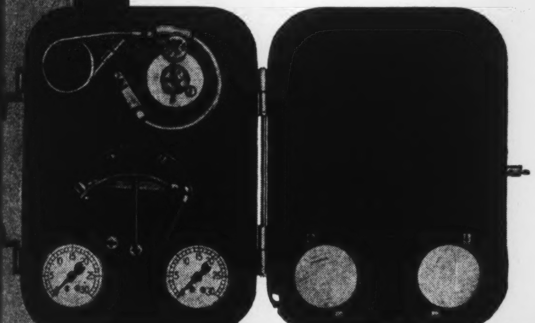
THE ARNOLD ENGINEERING COMPANY
SUBSIDIARY OF ALLEGHENY LUDLUM STEEL CORPORATION
General Office & Plant: Marengo, Illinois

SENSITIVITY

VACUUM RELIEF
VACUUM
BACK PRESSURE
BOILER STEAM
REDUCED PRESS
FLUID PRESS
PUMP DISC E
MAX - MI UM

Type 1400 handles both positive and negative pressures, from high vacuum to 10,000 psi. It is adaptable to services requiring high sensitivity or to wide throttling ranges for dampening sensitivity. Overcomes hunting action which makes lined out pressure control difficult. Adjustable in the field for snap action. Bourdon-tube actuated.

BS&B *Climax* TYPE 1400 PRESSURE CONTROLLERS



Here is how it works, explained step-by-step in this diagram. Simple, easy to maintain and ACCURATE!

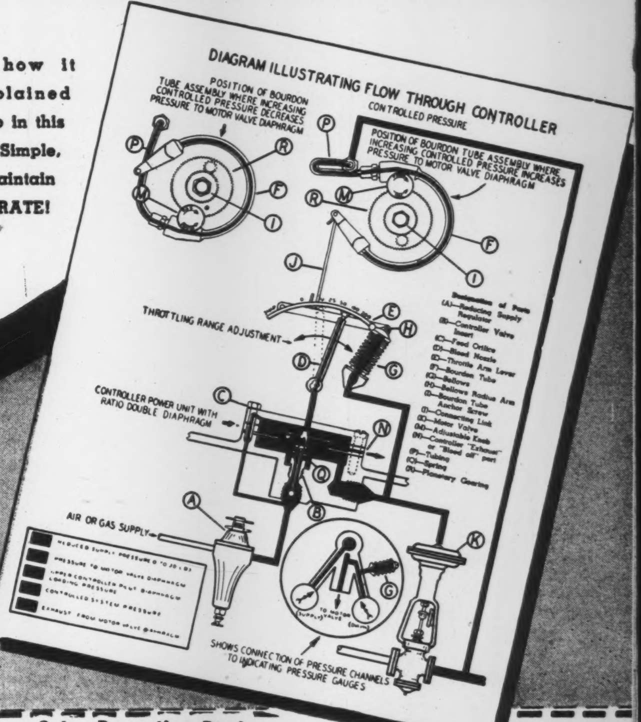


DIAGRAM ILLUSTRATING FLOW THROUGH CONTROLLER
POSITION OF BOURDON TUBE ASSEMBLY WHERE INCREASING CONTROLLED PRESSURE DECREASES PRESSURE TO MOTOR VALVE DIAPHRAGM
CONTROLLED PRESSURE
POSITION OF BOURDON TUBE ASSEMBLY WHERE INCREASING CONTROLLED PRESSURE INCREASES PRESSURE TO MOTOR VALVE DIAPHRAGM
P
R
M
F
I
J
THROTTLING RANGE ADJUSTMENT
E
H
D
G
CONTROLLER POWER UNIT WITH RATIO DOUBLE DIAPHRAGM
C
N
Q
A
B
K
AIR OR GAS SUPPLY
REDUCED SUPPLY PRESSURE 0 TO 30 LBS
PRESSURE TO MOTOR VALVE DIAPHRAGM
UPPER CONTROLLER PILOT DIAPHRAGM LOADING PRESSURE
CONTROLLED SYSTEM PRESSURE
EXHAUST FROM MOTOR VALVE DIAPHRAGM
TO MOTOR VALVE
(SUPPLY)
(DIAPH)
SHOWS CONNECTION OF PRESSURE CHANNELS TO INDICATING PRESSURE GAUGES
Designation of Parts
(A)—Reducing Supply Regulator
(B)—Controller Valve Insert
(C)—Feed Orifice
(D)—Bleed Nozzle
(E)—Throttle Arm Lever
(F)—Bourdon Tube
(G)—Bellows
(H)—Bellows Radius Arm
(I)—Bourdon Tube Anchor Screw
(J)—Connecting Link
(K)—Motor Valve
(M)—Adjustable Knob
(N)—Controller "Exhaust" or "Bleed off" port
(P)—Tubing
(Q)—Spring
(R)—Planetary Gearing

Now you can be assured positive and sensitive response to pressure changes, with a controller characteristic usually obtained only in more expensive type recording instruments. Climax builds it right, for long service under all conditions. A multitude of special adaptations are possible . . . Ask your BS&B-Climax Man today!

You Can Count on Your Climax Man

His sound backlog of experience in process controls is available for your own use. He will be pleased to help you beat a tough problem. He is readily available, just check the coupon. Naturally, all inquiries are held in strictest confidence.

Sales Promotion Dept.
BLACK, SIVALLS & BRYSON, INC.
Climax Controls Division
Sec. C4A-95-1 7502 East 12th St. Kansas City 3, Mo.

I would like the complete story of the BS&B-Climax Type 1400 Pressure Controller . . . catalog, data, diagrams, prices. ☐ I want a Sales Engineer to call.

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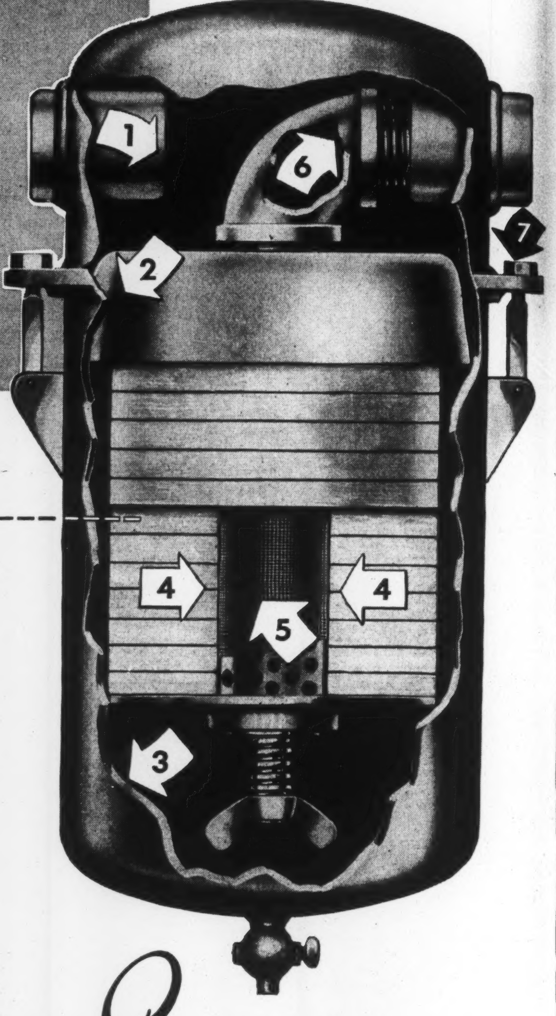
Removes Last Traces of Oil and Moisture from *INSTRUMENT AIR LINES....*



THICK FELT DISCS PROVIDE SUPER FILTRATION

DOUBLE ACTION PRINCIPLE REMOVES MOISTURE AND DIRT TWO WAYS—Here's the greatest pipe line filter ever developed for removal of every trace of foreign matter, condensed oil and moisture from instrument control lines. Air is cleaned by both *mechanical separation* and *filtration/absorption.* Air entering filter Inlet (1) strikes Deflector Cup (2) by which heavier droplets of water and dirt particles are directed to sides of Housing (3) and thence downward at high velocity to base where liquid and heavier particles are deposited. The *mechanically cleaned* air then passes at low velocity thru the Discs (4) which *filter* the air and *absorb* the last traces of oil and moisture. Clean, dry air passes out thru fine mesh Bronze Screen (5) and Outlet (6). Swing Bolts (7) on head for easy inspection are optional.

While originally designed for the protection of pneumatically operated control apparatus, these revolutionary filters are now used as a primary or final stage of filtration for an ever-increasing number of tools, devices and processes. Many highly successful installations are reported in which no other filter had proven satisfactory.

Request Bulletin B-1A, mentioning problem involved for specific engineering information. Please direct your inquiry to Dept. 63

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A complete range of sizes available, handling capacities from 5 to 100 CFM free air at 80 lbs. gauge pressure in standard pipe sizes from ¼" to 2". Model illustrated is AAPHS (swing-bolt head). Available also is Model AAPH, identical except for bolted-head construction.

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STAYNEW FILTERS

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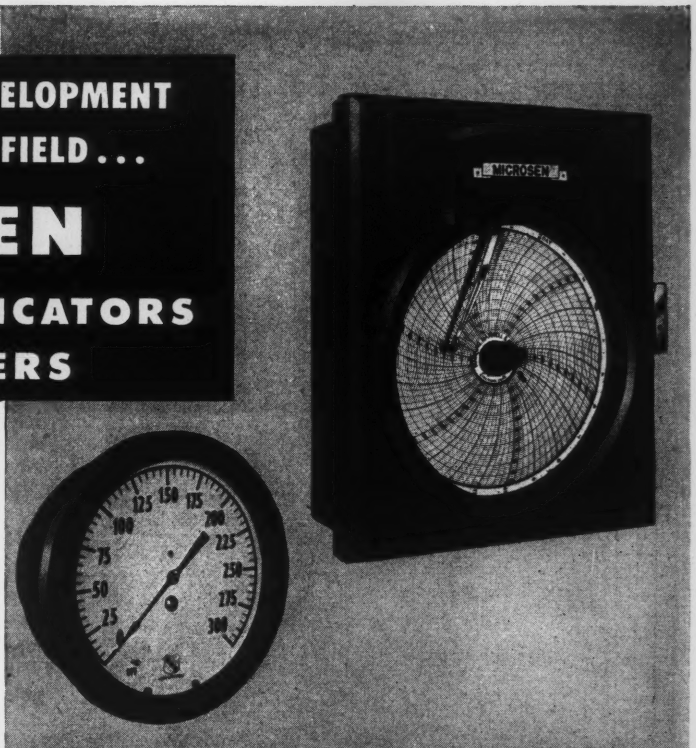
A NEW AND UNIQUE DEVELOPMENT IN THE PYROMETER FIELD...

MICROSEN

TEMPERATURE INDICATORS AND RECORDERS



Thermocouple actuated, Microsen Temperature Indicators and Recorders were designed to fill the need for a rugged, yet economical, type of electrical instrument capable of measuring temperature between minus 100° and plus 3000° F.

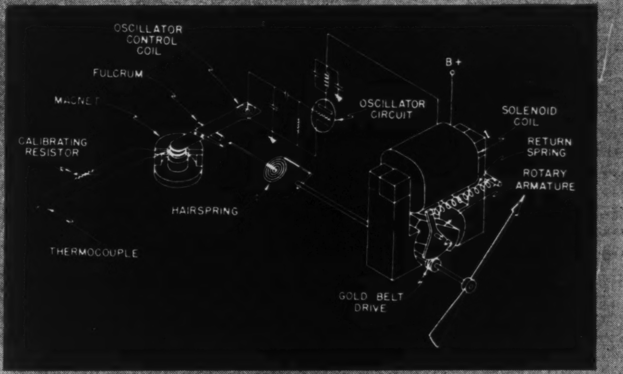
Power actuation and construction simplicity of these instruments supplant the delicate and fragile construction of millivolt pyrometers and eliminate the need for slidewires, standard cells, delicate moving contacts, or complicated mechanisms found in the more costly types of potentiometers.

Sensitive to low power input, the Microsen Balance assures precise performance in the measurement of temperature. Its characteristic rotary motion adapts it, particularly, to circular dial indication with consequent reduction of tendency to parallax error. A high torque rotary solenoid positions the pointer with "pin point" accuracy and allows the use of large indicating dials.

The Microsen Balance is enclosed in a sealed housing protecting all measuring elements from dust and corrosive vapors.

Thermocouple cold junction compensation is accomplished by a small, built-in, and heated chamber maintained at a constant temperature regardless of ambient temperature effects.

For complete details, write for Bulletin 404.



OPERATION OF MICROSEN BALANCE

The Microsen Balance is designed to maintain equilibrium between two forces, one proportionate to thermocouple emf, the second being dependent on pointer position.

A change in the thermocouple input causes a deflection of the Microsen beam. The change in proximity of the flag end of the beam to the oscillator coil detunes the oscillator circuit, causing a current change through the vacuum tube and the solenoid coil.

The solenoid armature rotates to position the pointer so that the hairspring torque is opposed and equal to the input torque. The mechanical indication is then being weighed in exact proportion to thermocouple input.

MICROSEN ELECTRICAL INSTRUMENTS

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Makers of 'Microsen' Electrical and 'American' Industrial Instruments, 'Hancock' Valves, 'Ashcroft' Gauges, 'Consolidated' Safety and Relief Valves. Builders of 'Shaw-Box' Cranes, 'Budgit' and 'Load Lifter' Hoists and other lifting specialties.

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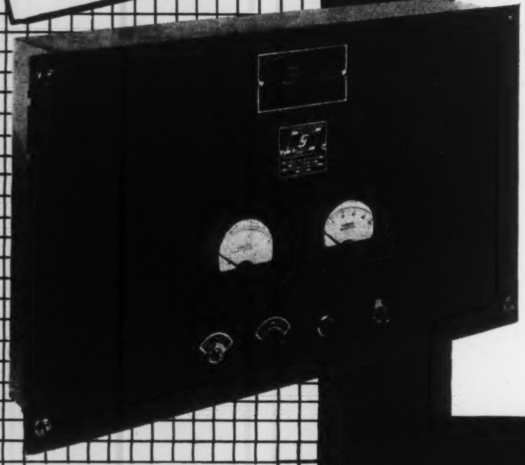
Like all Sorensen regulators, the NOBATRON is a painstakingly engineered combination of fine workmanship and top-quality components. That means accurate, trouble-free operation; long life!



MODEL NO. E-6-15

STANDARD MODELS

6-VOLT SERIES

- E-6-5
- E-6-15
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- E-6-100

12-VOLT SERIES

- E-12-5
- E-12-15
- E-12-30
- E-12-50

28-VOLT SERIES

- E-28-5
- E-28-10
- E-28-30
- E-28-70
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- E-125-5
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Model numbers indicate voltage and current; for example, E-6-5 indicates 6 VDC with 5 amp total capacity.

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Input voltage range	95-130 VAC; adapter transformers available for 230 VAC operation*
Output voltage range	Adjustable ± 10%
Regulation accuracy and load range	± 0.2% from 1/10 load to full load
Ripple voltage RMS max.	1%
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*Some high current units require three-phase input

Write for Complete Literature

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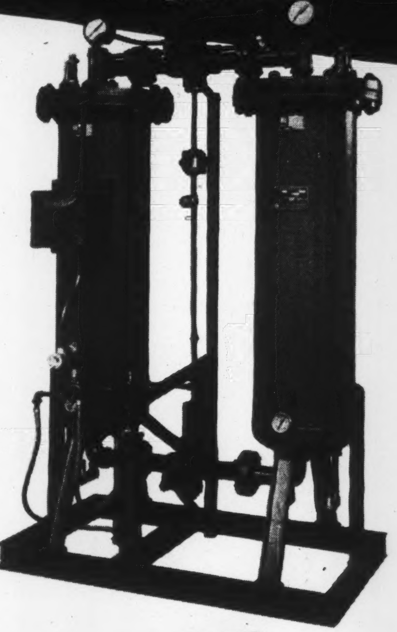

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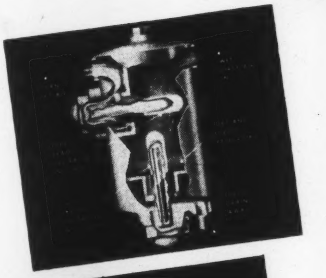

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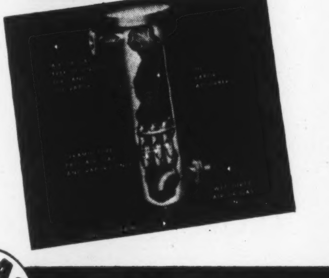
Designed for automatic and continuous removal of water, oil, water-oil emulsions and dirt from compressed air and gas lines. No moving parts. Removes particles even finer than 100 microns in diameter . . . processes from 10 to 500 cfm. Separation is achieved by ceramic filters...requires minimum of maintenance.



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Removes all traces of petroleum vapors—also water, oil, water-oil emulsions and dirt. This equipment adsorbs effectively all petroleum vapors present in compressed air or gas and provides clean supply for instrument, or other critical operation. Vapor adsorber is readily replaced when exhausted.

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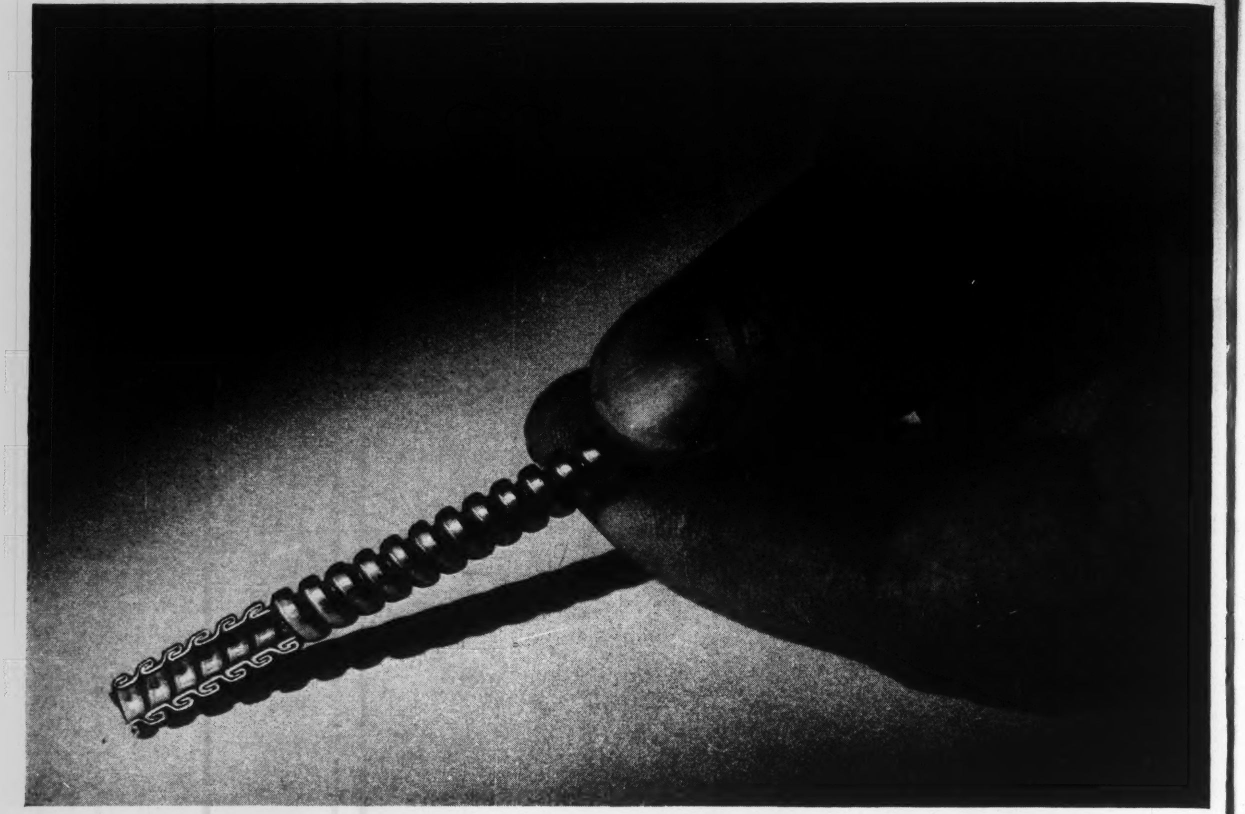

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Gas-tight and water-tight, with instant flexibility to conform easily to difficult layouts, this Penflex 4-wall interlocked metallic hose, in brass, steel or alloys, provides ideal shielding in radar and television applications or in any low-loss transmission problem.

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Penflex builds flexible metallic tubing from 5/32" I.D. to ½" I.D. in galvanized, bronze, stainless-steel and Monel metal. For quick solutions to problems on leakproof, flexible shielding for capillaries or conductors in the instrument field, Penflex has the answer. For engineering service and a complete line of metallic hose and tubing it's Penflex.

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FOR DEEP VACUUM OPERATIONS

W&T PRECISION INSTRUMENTS

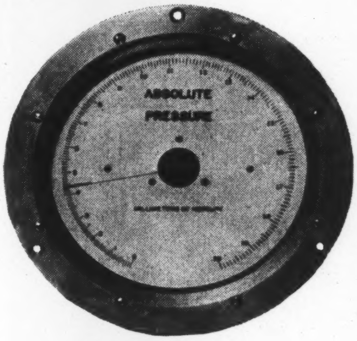
FA-193

THE W&T ABSOLUTE PRESSURE CONTACTOR

This sensitive, yet durable aneroid device is used for actuating an electric circuit at a preset value of absolute pressure.

Outstanding features of the Contactor, type FA-193, include:

Range of adjustment	0-2 mm Hg. and other ranges made to customer's specifications up to 800 mm Hg. absolute pressure.
Sensitivity	will make or break within 0.10 mm Hg.
Contact capacity	5 ma at 115 volts A.C.
Repeatability	0.10 mm Hg.
Vacuum-tight construction	
Over pressure protection	



FA-160 0-20 Scale

THE W&T ABSOLUTE PRESSURE INDICATOR

This precision instrument is used for quick, dependable indications of absolute pressures in the vacuum range. Pressure readings are independent of the nature of the gas. It is available in two dial sizes — $2\frac{3}{4}''$ and 6″.

Other features of the Indicator, type FA-160, include:

Range	0-20, 0-50, 0-100, 0-200, 0-410 and 390-800 mm Hg. absolute pressure.
Sensitivity	One part in 500
Accuracy	One part in 300
Over pressure protection	
Direct readings	
Rugged vacuum-tight construction	

0-100 Scale

THE W&T ABSOLUTE PRESSURE CONTROLLER

The Controller with its associated Electronic Relay furnishes precision control of absolute pressure and provides a continuous indication of absolute pressure. Independent adjustment of the "high" and "low" contacts is made through a magnetic clutch thus eliminating stuffing boxes and seals and ensuring leak-tight operations.

Outstanding features of the Controller include:

Range	0-20, 0-50, 0-100, 0-200, 0-410 and 390-800 mm Hg. absolute pressure.
Sensitivity	One part in 500
Accuracy	One part in 300
Relay contact capacity	5 amps, 110 Volts, 60 cycles non inductive load.
Fast accurate response	
Over pressure protection	
Vacuum-tight construction	

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ELECTRICAL MECHANISMS AND PRECISION INSTRUMENTS
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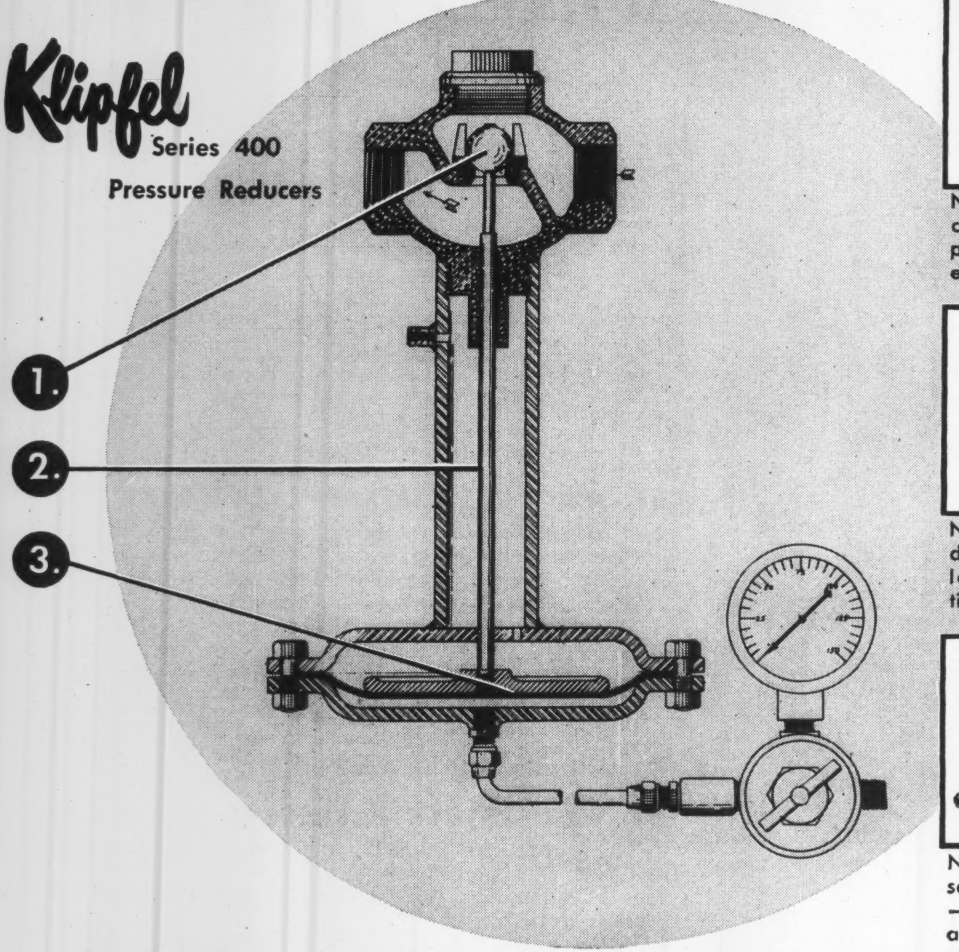
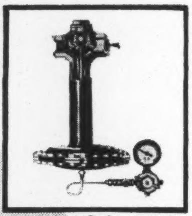
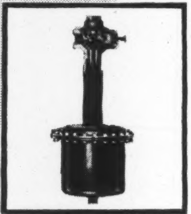
Klipfel Series 400
Pressure Reducers

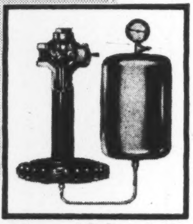




No. 432 with constant air supply—for quick, easy adjustment.



No. 431 with air dome—for isolated installations.



No. 430 with separate air tank—for variable ambient temperature.

Accurate low-cost regulators . . .

FOR longer service with negligible maintenance, operating parts are reduced to just three, inner valve, stem and diaphragm, in the Klipfel 400 Series air-loaded Pressure Reducing Valves. In addition, these 400 Series Valves provide exceptionally close regulation for an unusually low initial cost.

The stainless steel ball inner valve is a perfect sphere, extremely hard and well guided to close to a tight seat. Easily reseated if necessary . . . is self-cleansing and non-sticking. Diaphragm is always in balance . . . no stress, no bursting. Regulation is accurate and easily controlled. For increased safety, flow automatically shuts off in case of diaphragm failure.

For full data on the Klipfel 400 Series Valves, for steam, air, water or gas, write Dept. DA-1 for Bulletin No. 148.

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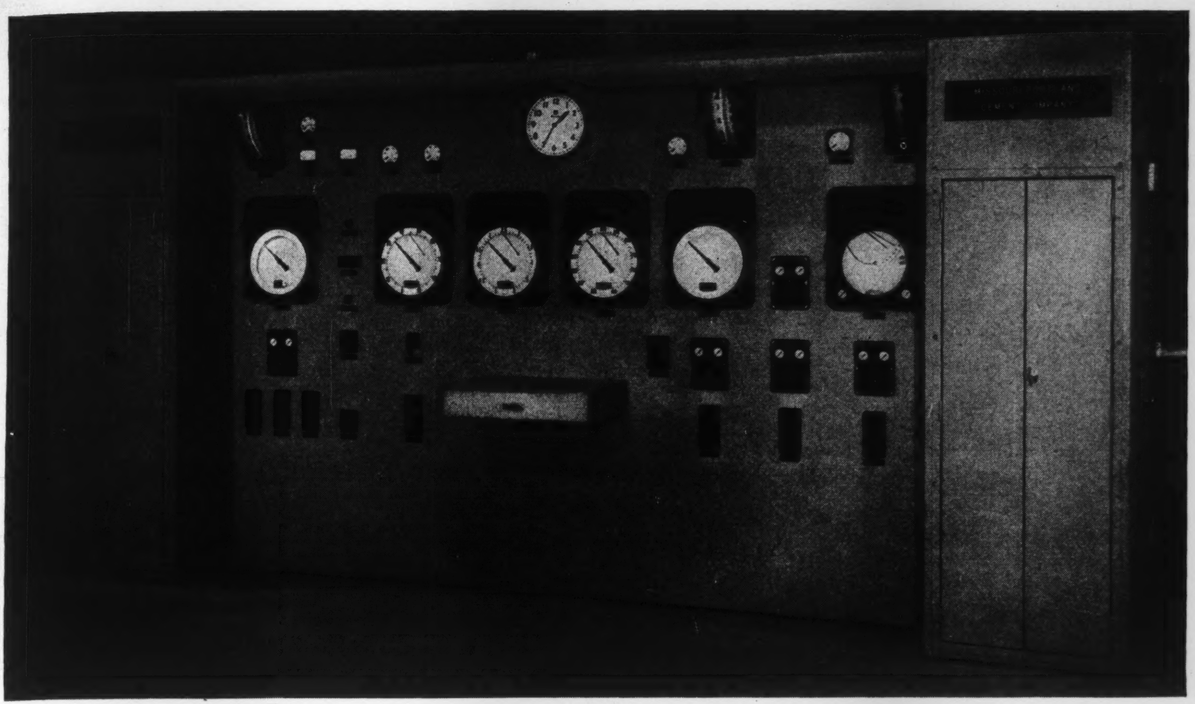

Main Panel Board for control of 3000 bbl per day Kiln at Missouri Portland Cement Company, St. Louis, Missouri.

3 Ways Better

...Bailey Control for Rotary Kilns

Bailey Control for Rotary Kilns gives you better performance three ways:

1. Economical Operation
2. Uniform Quality of Product
3. Reduced Maintenance

These are advantages which can be achieved when all phases of kiln operation are coordinated to work together as a team. Here's how Bailey Kiln Control can help you get all three.

ECONOMICAL OPERATION

With Bailey Combustion Control you can be certain that you are getting maximum product for every unit of fuel you burn. Bailey Control closely guards the Fuel-Air Ratio, Hood Draft, Fuel Feed, Clinker Cooling and the Temperature of Air for Combustion.

UNIFORM QUALITY OF PRODUCT

Bailey Instruments and Controls can help you achieve a uniform high grade product. Measurements of temperatures, kiln speed, combustibles content, and oxygen content can be transmitted to recorders on centrally located control boards like the one shown. There is no sacrifice of accuracy or speed of response. High temperature alarm contacts may also be provided with Bailey Pyrometers as a further aid in achieving optimum uniformity of product.

REDUCED MAINTENANCE

By maintaining uniform temperatures and excess air conditions in the kiln, Bailey Controls help to reduce to a minimum costly refractory repairs and wear and tear on auxiliary equipment.

Bailey Meter Company has a staff of engineers who are experts in the control of rotary kilns. Assure yourself of optimum kiln performance. Let one of these men help plan your Kiln Control System.

P-22

BAILEY METER COMPANY

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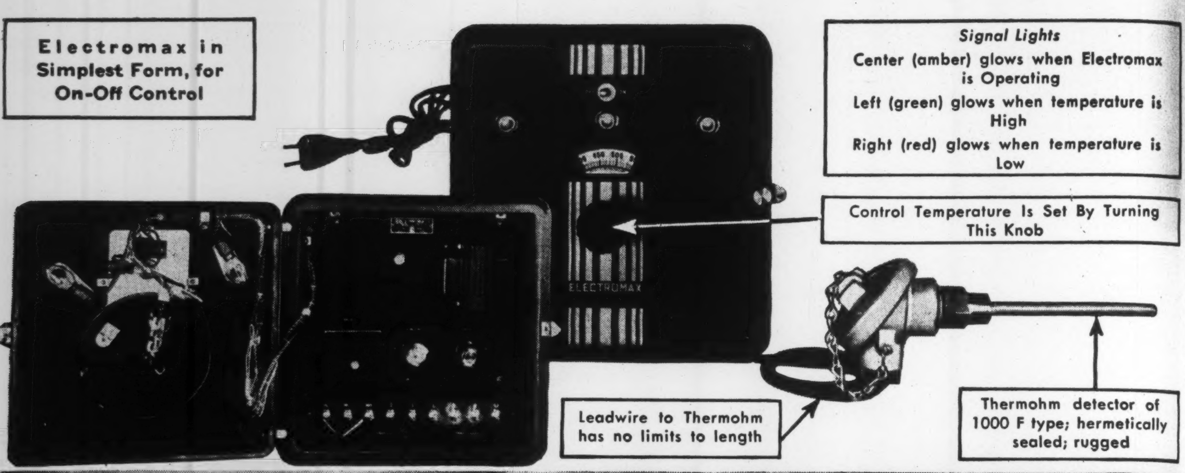
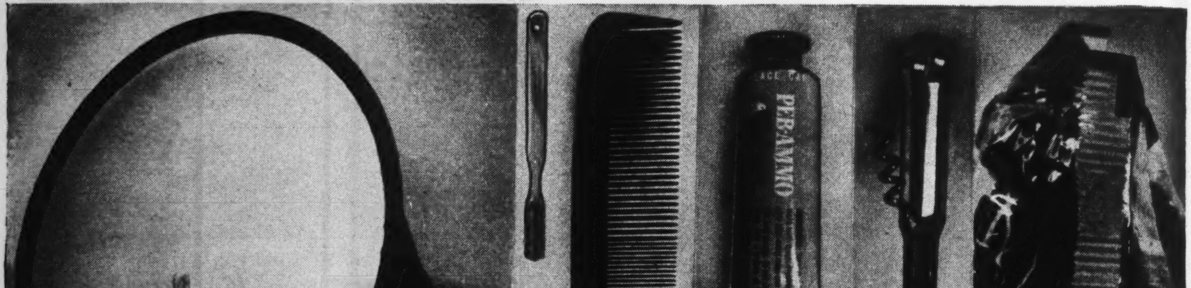
Controls for Processing

TEMPERATURE
PRESSURE
% OXYGEN
% COMBUSTION
FLOW
LEVEL
DENSITY
RATIO


Electromax in Simplest Form, for On-Off Control
Signal Lights
Center (amber) glows when Electromax is Operating
Left (green) glows when temperature is High
Right (red) glows when temperature is Low
Control Temperature Is Set By Turning This Knob
ELECTROMAX
Leadwire to Thermohm has no limits to length
Thermohm detector of 1000 F type; hermetically sealed; rugged



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You can specify any one of 3 types of control action:

1. On-Off or 2-position Control
2. Proportioning, automatic reset and rate (D.A.T.) Control
3. Proportioning and manual reset (P.A.T.) Control

For further information, write our nearest office, or 4955 Stenton Ave., Philadelphia 44, Pa.

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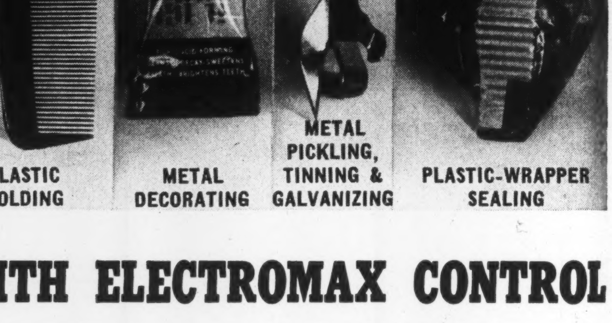
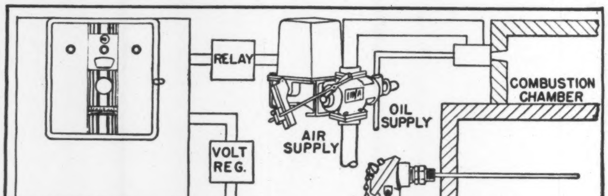

RELAY
COMBUSTION CHAMBER
OIL SUPPLY
AIR SUPPLY
VOLT REG.
115 VOLTS
OVEN

ELECTROMAX FOR PROCESS HEATED BY GAS, OIL OR STEAM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HEATER
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115 VOLTS

ELECTROMAX FOR PROCESS HEATED BY ELECTRICITY

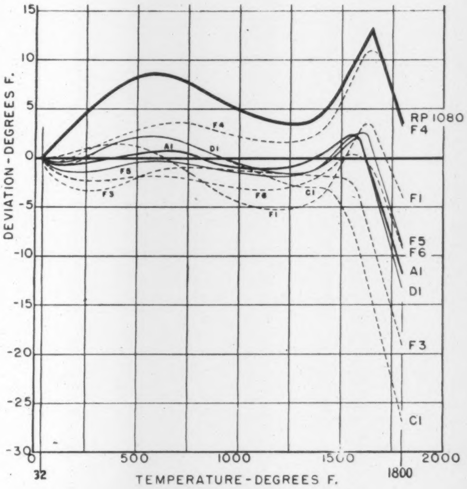
Instruments THE MAGAZINE OF Measurement and Control

M. F BEHAR, Editor

Standardization of I-C Thermocouple Tables

A Guest Editorial by the Temperature Measurement Section, National Bureau of Standards

The iron-constantan thermocouple is widely used in industry for measurement of temperatures up to 1500 F. Yet it is the only type of thermocouple for which uniformity of commercial practice has not been established in this country. Recently, at the request of the Scientific Apparatus Makers of America, the National Bureau of Standards has undertaken to derive a temperature-emf. reference table for iron-constantan thermocouples which would be suitable for adoption as a standard. The temperature-emf. tables for thermocouples which the National Bureau of Standards has issued from time to time have been used extensively in science and industry, not only to convert thermocouple voltages into the equivalent measured temperatures but also in the preparation of purchase specifications for thermocouple wire and in defining the relation between impressed emf. and scale reading for pyrometers which indicate temperature directly. In practice the calibration of an individual thermocouple is ordinarily given in terms of deviations from such a reference table. Since it is usually not convenient to change the scale of a direct-reading pyrometer to compensate for variations in the thermocouples which may be used with it, thermocouples are commonly purchased under specifications which ensure that they will correspond closely to the graduation of the particular model of pyrometer used.



Deviations observed at NBS between readings of sample I-C couples and the 1913 (L & N) temperature-emf. table are shown by dashed and fine continuous lines. Heavy line indicates differences between the RP 1080 and the 1913 tables.

Some time ago, an investigation[1] of iron-constantan thermocouples by the Bureau disclosed that the thermocouples of this type which were then commercially available did not follow closely any of the several temperature-emf. relations for iron-constantan in use by pyrometer manufacturers. The Bureau therefore derived a new table, usually known as the RP 1080 table, which represented the average behavior of the iron-constantan thermocouples on the market. However, most of the various manufacturers made efforts to develop and make available thermocouples which would correspond to the temperature-emf. tables they were using. As a result, a number of widely diverse reference tables for iron-constantan thermocouples are still in use.

In an effort to achieve greater uniformity, the Recorder-Controller-Section of the Scientific Apparatus Makers of America, representing several of the pyrometer manufacturers, in 1948 adopted the temperature-emf. relation known as the 1913 (L & N) table[2] as a tentative standard for iron-constantan thermocouples over the range from 32 to 1400 F. This relation was chosen because it is in wider use than any other. However, experience has shown that it is apparently not possible to produce a thermocouple which will correspond precisely to the 1913 table over the entire range from 32 to 1400 F. Morever, any thermocouple which closely matches this table in the range below 1400 F. will deviate greatly from it in the range above 1400 F. The SAMA therefore requested the National Bureau of Standards to derive a reference table which would be free from these defects. It was felt that such a table should be as close to the 1913 table as possible, yet should represent the properties of an actual commercially-available thermocouple.

Eight different lots of matched iron and constantan wires were submitted to the Bureau by four members of SAMA. The thermal emf's of the various wires versus platinum were measured in the Bureau's pyrometry laboratory from 32 to 1800 F. From these data, the corresponding thermal emf's for the I-C thermocouples were computed. In addition, chemical and spectrographic analyses of the iron samples and hardness determinations were made. It was found that the spread in the thermal emf's of the I-C thermocouples below 1400 F. was not large compared to usual commercial tolerances, even though the iron samples differed among themselves by as much as 0.8 millivolt at 1400 F. (equivalent to about 20 degrees in the indication of an I-C thermocouple) and the constantan samples differed similarly. Present preference is to base the new SAMA table upon the temperature-emf. relation of thermocouple A-1, since this thermocouple deviates least from the 1913 table in the range of normal use.

The question may now be raised whether the field of use of this proposed new table can be broadened through industry-wide acceptance. Support by this Bureau for any new table (taking the form of official publication and possibly resulting in inclusion in a Federal Specification) might conceivably cause hardship to suppliers and users of I-C thermocouples who have based their operations on the RP 1080 table. Thus, it is felt that the views of all interested parties should be obtained as a prerequisite to the adoption of this table. The questions that naturally occur if the proposed table can be adopted are the following: Is industry-wide standardization on a single reference table for iron-constantan desirable? Is the 1913 table, or a close approximation to it, acceptable for this purpose? What degree of hardship will be occasioned by abandonment of the RP 1080 table? Replies to these questions, and comments, can be addressed to the Temperature Measurements Section, National Bureau of Standards, Washington 25, D.C.

(1) Reference tables for iron-constantan and copper-constantan thermocouples, William F. Roeser and Andrew I. Dahl, *National Bureau of Standards Journal of Research*, Vol. 20, 1938, Research Paper 1080.

(2) Identical with the tables given in *International Critical Tables*, Vol. I, 1926, page 59; and in *Bureau of Standards Technical Paper* 170. 1920, page 306, Table IV, Col. L.

High-speed Direct-trace Recording Methods

By **ROGER BROWN LOUCKS, Chairman of Department of Psychology, University of Washington, Seattle, Wash'n.**

ABSTRACT—Various high-speed direct-trace recording methods are described that do not involve photographic techniques. Some of the systems discussed will record signals having frequencies of several thousand cycles per second. All of the techniques are designed to provide a wide-excursion linear record which is not subject to the artifacts that arise from the inertia of the moving stylus in conventional ink writers or from the tendency of servomotor systems to "hunt." The recorders can be used with a wide variety of pick-up devices and most of the systems which are described can be constructed inexpensively.

IT has become increasingly common in psychological and physiological studies for experimenters to rely on photographic and electrical recording devices. As has been previously noted,[2] the processing of photographic film or sensitive paper becomes an extremely laborious and time-consuming task when continuous records are required. One limitation of most techniques involving the photographic recording of movements arises from the fact that the subject must be immobilized. Thus, when eyelid movements are being recorded, it is common practice to have the subject maintain a stationary position by holding a fixed biting board with his teeth. A further limitation of most photographic techniques is the delay that commonly ensues between the occurrence of a response and the inspection of the record, necessitated by the time required to develop the film. (This delay can be reduced where it is feasible to use Polaroid-Land film.)

Electromechanical ink writing systems have serious frequency limitations and introduce errors because of the inertia of the moving element. The so-called high-speed photoelectric recorder and the various servomotor recorders are limited to a response frequency of approximately ten cycles per second, or less. They also have a tendency, at the higher frequencies, to introduce errors of overshooting and "hunting." The various electromagnetic and crystal ink writers have a response frequency limitation of approximately 100 cps. and, if they are to deliver linear deflections for a wide spectrum of frequencies, their effective range is considerably below this limit. In many instances where the frequencies of a physiological phenomenon approach 100 cps. there will be certain harmonics or transients which are higher than the fundamental, and the resulting record which is traced by the ink writer may be quite inaccurate. Most high-speed ink writers have the disadvantage of tracing on an arc and being limited to relatively small angular excursions.

Suggestions have been published for manually tracing a non-recurrent record on a cathode-ray tube which has a long-persistence phosphor,[2,3] but this technique is not very satisfactory for recording phenomena continuously, over an appreciable period of time.

The various high-speed direct-trace systems to be described were developed in order to provide linear deflections over a wide range of frequencies, to overcome the errors arising from the inertia of an ink-writing stylus, to obviate the limited excursions of the common electromagnetic or crystal ink writers, and to obviate the need for the processing of photographic records.

I. RECORDERS WITH FIXED STYLUSES COUPLED TO ELECTROMECHANICAL PICK-UPS

The fixed-stylus recorder consists of thirty or more metal styluses evenly spaced in a supporting insulator which is transverse to the direction of movement of the recorder paper. Teledeltos or similar current-sensitive paper is used for recording, and the styluses touch the surface of the moving paper. Each stylus is connected in the plate circuit of a 6N7 triode. (The 6N7 vacuum tube has two triodes within one metal envelope.) The grid of each triode is connected to one segment of a commutator comprising the pick-up unit. Normally, the grids of all triodes are held at a negative bias to block plate current but, when the switch arm of the commutator assembly touches one of the commutator segments, it reduces the grid bias of its respective triode, and current flows through the plate of that tube and the stylus to which it is connected, thus making a mark on the Teledeltos paper at one particular position on the chart. If the paper is a continuously-moving chart, a line will be traced and, if the switch arm of the commutator assembly is moved back and forth, a wavy line will be traced as the current flows through the various styluses in sequence. Fig. 1 is the basic circuit for the fixed-stylus recorder.

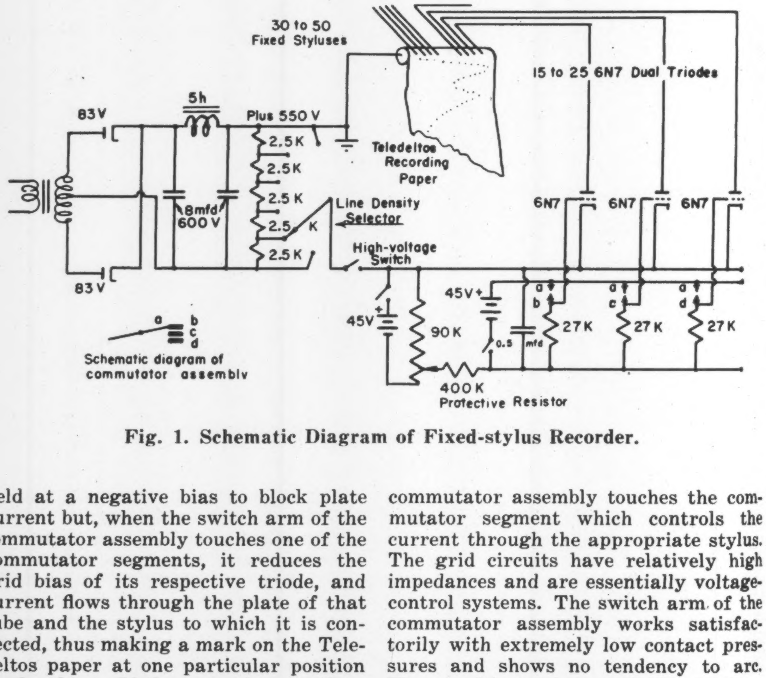


Fig. 1. Schematic Diagram of Fixed-stylus Recorder.

In order to provide a light and compact commutator assembly, a small arc-shaped segment of a 25-watt 80-meter air inductor (commonly used in amateur radio transmitting sets) is dressed down in a lathe until the successive turns of the helix are exposed so as to give a flat highly-polished surface which consists of alternating segments of plastic insulation and metal commutator strip. In order to record eyelid responses, this light commutator assembly is mounted on one bow of a plastic spectacles frame. A small piece of photographic film is fastened to the eyelid with collodion and the outer end of this strip is articulated with a featherweight switch arm in the commutator assembly.

Each triode of the recording system conducts on an all-or-none basis as its respective grid bias is switched off or on through the commutator assembly. As a consequence, the recording system is singularly stable. Because the grid biases are non-critical, this type of recording device eliminates the problems of calibration inherent in the majority of electrical recorders. A trace at a particular position of the paper appears only when the switch arm of the commutator assembly touches the commutator segment which controls the current through the appropriate stylus. The grid circuits have relatively high impedances and are essentially voltage-control systems. The switch arm of the commutator assembly works satisfactorily with extremely low contact pressures and shows no tendency to arc. The resulting friction of the featherweight switch arm against the highly polished commutator assembly is so slight that there is no appreciable backward action[6] when the eyelid of the human subject is coupled to the switch arm. Furthermore, various types of electrical indicating instruments have sufficient power to drive their pointers over such a commutator assembly and can thus be used to obtain a trace of the pointer movements.

The fixed-stylus recording technique obviously gives a record which consists of incremental changes in amplitude rather than a continuously varying trace. It should be recognized, however, that practically all records must eventually be quantified. Inasmuch as the pick-up unit has approximately 15 commutator segments per centimeter, and in view of the fact that by printing circuits from a photograph it is possible to attain almost any degree of resolution in the commutator, the division of the record into discrete steps should not be regarded as a limitation but, rather, as an aid to measurement. The commutator assembly actually in use at the present time has uniformly-spaced metal strips but, by printing the circuit from a photograph, pie-shaped segments or logarithmically-spaced segments could be obtained.

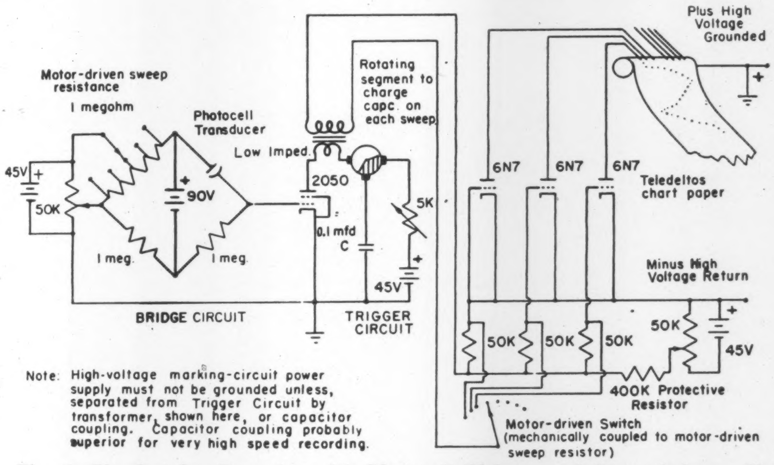
An extremely important characteristic of this recording system is that several records can be traced simultaneously with one set of fixed styluses. Two commutator assemblies are merely connected in parallel. If greater differentiation is desired when several records are traced simultaneously, different sets of grid resistors can be added to the various pick-up units so that traces of different densities will be registered by the respective signals.

A recording system of the type just described has been used daily for many months and has proved to be exceptionally reliable.

II. FIXED-STYLUS RECORDERS COUPLED TO CONTINUOUSLY-VARIABLE PICK-UPS

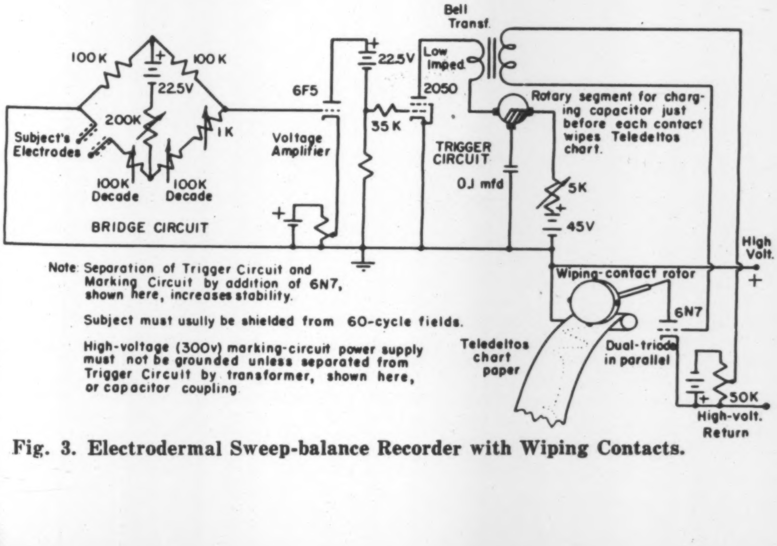
It is sometimes considered desirable to reduce the backward action of a pick-up device to an absolute minimum. Thus, in the recording of an eyelid response from a small animal, it has been found advantageous to fasten an artificial eyelash to the lid with collodion so that it interrupts a light beam falling on a photocell supported on the animal's head[3]. With a small artificial eyelash, floating freely, backward action is infinitesimal. The fluctuating d-c. voltage which develops across the load resistor of the photocell can be used to control a sweep-balance recording bridge.

A sweep voltage is produced by means of a motor-driven commutator assembly. Two switch arms, insulated from each other but mechanically coupled, are rotated by a motor. The switch arms pass over two independent sets of commutator segments. Fixed resistors are connected between successive metal strips in one commutator assembly. This commutator with its motor-driven sliding contact constitutes a variable resistor and, if there is a potential across the resistor, the rotating switch arm picks up a voltage which varies in a stepwise manner from one end to the other. The second set of commutator segments is connected to the grids of the 6N7 triodes which control the current through a set of fixed styluses. The motor-driven variable resistor is placed in one leg of a bridge circuit and the photocell in the opposite side of the bridge. In moving over successive commutator segments, the switch arm reaches a point where the voltage differs just sufficiently from the voltage across the photocell to discharge a 2050 thyratron. This is close to the point at which the bridge is balanced, and will be referred to, hereafter, as the "null point," even though it is only an approximation. The discharge of the thyratron gives a brief positive voltage surge in the grid circuit of the 6N7 triode to which the second switch arm is momentarily connected (i.e., by way of its respective commutator segment). The current for the thyratron discharge is obtained from a capacitor which can be filled at only one point in the rotation of the switch arm. This insures that only one mark will be made per revolution of the switch arm. Each fixed stylus corresponds to a point on the variable resistor, and its position with respect to the edge of the paper represents the voltage at the corresponding point on the resistor. If the voltage developed by the photocell varies, the bridge is successively balanced when the rotating switch arm wipes the specific commutator segments which have equivalent voltages. As the null point at which the bridge voltages are equated shifts up and down, a wavy line of dots appears at the corresponding styluses. Fig. 2 presents a schematic circuit diagram for this recording system.


Motor-driven sweep resistance
I megohm
45V
+
50K
+
90V
Photocell Transducer
I meg.
I meg.
BRIDGE CIRCUIT
Rotating segment to charge capc. on each sweep
Low Imped.
2050
0.1 mfd
C
5K
+
45V
TRIGGER CIRCUIT
Plus High Voltage Grounded
+
6N7
6N7
6N7
Teledeltos chart paper
Minus High Voltage Return
50K
50K
50K
50K
+
45V
400K Protective Resistor
Motor-driven Switch (mechanically coupled to motor-driven sweep resistor)

Note: High-voltage marking-circuit power supply must not be grounded unless, separated from Trigger Circuit by transformer, shown here, or capacitor coupling. Capacitor coupling probably superior for very high speed recording.

Fig. 2. Fixed-stylus Recorder with Photocell Pick-up and Sweep-balance Circuit.


100K
+
100K
22.5V
200K
1K
Subject's Electrodes
100K Decade
100K Decade
BRIDGE CIRCUIT
6F5
Voltage Amplifier
+
+
22.5V
35K
Low Imped.
Bell Transf.
2050
TRIGGER CIRCUIT
0.1 mfd
Rotary segment for charging capacitor just before each contact wipes Teledeltos chart.
5K
+
45V
High Volt.
+
Wiping-contact rotor
6N7
Teledeltos chart paper
Dual-triode in parallel
+
50K
High-volt. Return

Note: Separation of Trigger Circuit and Marking Circuit by addition of 6N7, shown here, increases stability.

Subject must usully be shielded from 60-cycle fields.

High-voltage (300v) marking-circuit power supply must not be grounded unless separated from Trigger Circuit by transformer, shown here, or capacitor coupling.

Fig. 3. Electrodermal Sweep-balance Recorder with Wiping Contacts.

This general method of tripping a thyratron when a bridge is balanced can be used in conjunction with a variety of pick-up devices such as thermistors, thermocouples, strain-gage elements, etc. In certain instances some amplification must be introduced between the bridge and the trigger element. By using decade resistance boxes it is possible to spread out the record so that changes of a few hundred ohms take up the full width of the record even though the circuit's total resistance may be many thousand ohms.

It is important to note that a number of independent functions can be traced simultaneously on one chart by adding commutator bridge assemblies which match the respective pick-up units being employed. In the case of skin resistance measurements, for example, one trace can be used to record the base resistance level while another records small fluctuations of a few hundred ohms.

In order to record eyelid responses it is desirable to use a high-speed motor to sweep the commutator switch arm. With a motor speed of, e.g., 6000 rpm, and with four switch arms per commutator assembly, 400 null points can be recorded per second. This gives a temporal separation of only 0.00025 seconds between successive trace points and provides a satisfactory record for almost any type of muscle displacement, pulse wave, respiratory pattern, etc. To record the action potentials from muscle or nerve fibers necessitates a higher switching rate and the cathode-ray commutator tube, to be described below, is a more suitable device for the recording of signals with these higher frequencies.

III. Fixed-stylus Recorders Coupled To Mirror Galvanometers

It might be noted, for the sake of completeness, that the fixed stylus recorder can be coupled to a sensitive galvanometer by placing a series of photocells in the path of the light beam which is reflected from the mirror. Each of these photocells would then be connected to the grid of a 6N7 triode so that, as the light beam from the galvanometer mirror fell on a particular photocell, a trace would appear at its respective stylus. Inasmuch as the description of high-speed recorders is the major objective of this article, further consideration will not be devoted to galvanometer systems since the more sensitive instruments have a relatively long characteristic time.

IV. Fixed-stylus Recorders Coupled to Cathode-ray Commutator Tubes

The cathode-ray commutator tube is essentially an electronic switching device. It consists of an electron gun, similar to that used in the conventional cathode-ray tube, and a series of metal targets on the opposing surface of the envelope, which have wires coming to the outside of the tube. The electrons emitted by the hot cathode can be aimed by deflecting plates so as to impinge on any specific target on the inner surface of the envelope. (In the commutator tube designated as the "Cyclophon," the secondary electrons emitted from the target which is being bombarded are collectd by an aperture plate so as to increase the output current strength.) By connecting each commutator target, by means of a suitable capacitance-resistance circuit, to one of the 6N7 grids of the fixed-stylus recorder described above, it should be possible to actuate each stylus as the electron beam is swept successively from one target to the next. Thus, for example, the small fluctuating voltages of nerve or muscle fibers, when suitably amplified and coupled to the deflection plates of the electron gun within the commutator tube, could be used to deflect the electron beam of the commutator tube back and forth across the opposing targets. As each target was bombarded, a trace would be registered at the corresponding position on the Teledeltos recording paper. Commutator tubes commercially available generally have targets which are arranged in a circle but the Electronic Tube Corporation of Philadelphia is in a position to construct cathode-ray tubes with other target designs. A linear arrangement of targets would be particularly convenient (although not essential) to use in conjunction with the fixed-stylus recorder, which has its points evenly spaced at right angles to the motion of the recording paper.

Excluding the frequency limitations of the pick-up unit—and in recording action potentials the voltages to be amplified are picked up directly from electrodes placed on the tissues—this type of recording system should trace

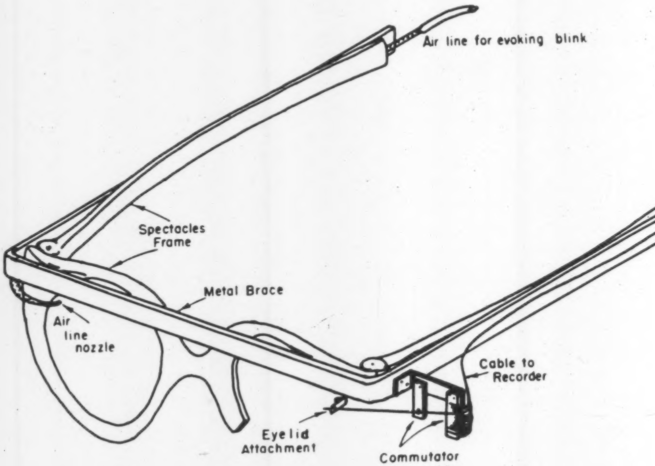


Fig. 4. Commutator Pick-up for Eyelid Recording.

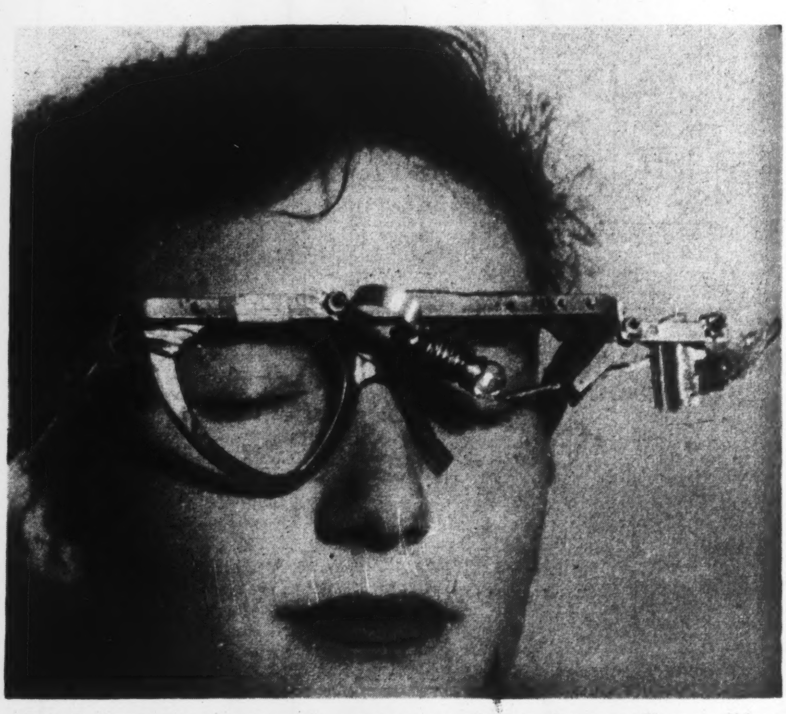
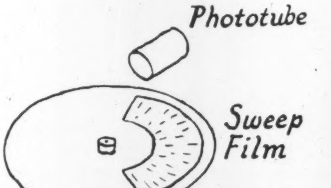


Fig. 5. Spectacles frame with commutator pick-up for recording eyelid responses. The frame supports an electric light bulb (omitted in Fig. 4) which provides a visual signal in conditioning experiments, and an air-line nozzle which can be used to elicit a reflex blink. This apparatus is used to investigate some of the basic characteristics of twilight vision, i.e., when the subject is dark-adapted, as contrasted with daylight vision. By using a similar pick-up which is adapted to small animals it is possible to compare the various types of reflex and conditioned lid responses in species that have different types of eye structures. In this way information can be gathered regarding the specific functions of particular sensory and neural structures comprising the visual system.

frequencies of several thousand cycles per second inasmuch as distinct marks representing 1/10,000 of a second can be readily recorded. This means that the whole spectrum of muscle and nerve action potentials could be recorded graphically with satisfactory fidelity. A microphone pick-up coupled to an amplifier could be used similarly to obtain a direct-trace of the lower end of the audio frequency spectrum. It would also appear that with a suitable scanning system the fixed-stylus recorder could be used for "very-high-speed" facsimile transmission.

In addition to the system described just above, in which the signal is brought to the deflection plates so as to sweep the electron beam over the targets, it should be possible to use the commutator tube to record successive null-point bridge measurements at an extremely high rate of speed. One technique would involve the use of two commutator tubes in somewhat the same manner as the motor-driven switch and the mechanically-coupled variable resistor were employed in the system described above in Section II (see Fig. 2). One of the commutator tubes, "A," would have its targets coupled in sequence to the grid circuits of the fixed-stylus recorder in the manner described at the beginning of this section (IV). In the second commutator tube, "B," fixed resistors would be connected between the successive metal targets, externally. (The Electronic Tube Corp. manufactures a cathode-ray tube with an internal potential-divider strip, but a resistor divided into discrete segments would be preferable for the present application.) A saw-tooth voltage generator could be used to sweep the beams in both commutator tubes synchronously. When the electron beam of the variable resistor tube, "B," reaches the target at which the IR-drop balances that of the pick-up, a trigger tube would fire. (The 2050 thyratron has great sensitivity but an appreciable deionization time, and in certain applications a "flip-flop" vacuum-tube circuit might be essential for very-high-speed triggering.) The trigger circuit would be used to control the accelerating voltage of the electron gun within commutator tube "A" serving as an electronic switch for the triodes of the fixed-stylus recorder. This momentary accelerating voltage would cause the electrons of commutator tube "A" to impinge on the particular target to which the saw-tooth sweep voltage had aimed the beam. A mark would thus be registered at the fixed stylus corresponding to the bombarded target to which it was coupled by a 6N7 triode. As the saw-tooth voltage on the deflecting plates repeatedly sweeps the electron beam of tube "B" over the commutator points of the variable resistor, successive null points at which the bridge is "balanced" would be recorded as a series of marks at the corresponding fixed styluses. It is important to note that the sweep-balance type of circuit would record only one mark per saw-tooth sweep whereas the system described at the beginning of this section (in which the signal is led directly to the beam deflection plates) would register the full pattern of the signal voltage. Using the electronic commutator tubes in a sweep-balance circuit, a saw-tooth frequency of 1,000 cps. would record only 1,000 null points per second from any signal, regardless of its frequency. This would be adequate to give the pattern of signals much below 1,000 cps. but not for a signal of that same frequency. In contrast, the first method described in this section would record a 1,000-cps. signal quite satisfactorily. It should also be noted that the precision of the record obtained with the sweep-balance circuit will depend upon the stability of the trigger circuit. The record obtained when the signal is led to the beam deflection plates would appear to have inherently greater reliability. With high frequencies the two plates within one 6N7 envelope might have to be connected to one stylus so as to provide enough current density to give a legible trace.



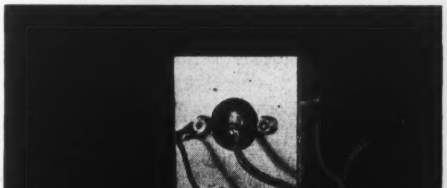


Fig. 6 (left). Diagram of Phototube Sweep-balance Spark Recorder.
Fig. 7 (right). Photograph of Phototube Sweep-balance Spark Recorder.

V. MOVING-STYLUS SWEEP-BALANCE RECORDERS

Although the primary objective of this article is the description of various types of fixed-stylus recorders, and although a stepwise recorder can be substituted for almost any continuously-varying recorder by making the increments small enough, the continuously-varying recorder with a moving stylus might be discussed at this point because of its general usefulness and the low cost of construction.

The moving-stylus recorder is based on the sweep-balance principle and can be used in the same way, essentially, as the system for making bridge measurements with the fixed-stylus recorder which was described in Section II. Its major advantage over the previous technique is that it requires a much smaller number of circuit elements and so is less expensive to construct. It has the frequency limitations of a mechanical sweep system in which only one null point can be recorded for each cycle of the sweep voltage.

One of the earlier recording mechanisms involving the basic sweep-cycle principle is the Farnborough engine indicator, although this was mechanical in nature. Recently, descriptions of sweep recorders which use an electric current to make a trace have been published by Smith,[5] Keinath,[1] and Loucks.[4] The latter two references present circuits which specifically utilize a sweep-balance bridge circuit. Reference 4 describes a recording mechanism which utilizes a photocell sweep circuit that registers 60 null-point determinations per second (Figs. 6 and 7). Since the description of this high speed sweep recorder was published,[4] the technique has been considerably advanced. It has been found that a ball-shaped contact, or series of contacts, on the periphery of a disk can be rotated so as to wipe the surface of a moving chart of Teledeltos paper at rates of 3600 rpm. or more. (The paper is drawn through a slightly concave chute or guide so that the wiping contacts touch the paper over an arc of about three linear inches but do not catch on the edge of the paper. Another technique involves the use of a metal tape or chain which has studs, spaced at intervals, that move across the surface of the paper.) Using a moving stylus in contact with Teledeltos paper makes it possible to reduce greatly the voltage and power required for the spark tracing systems previously described.[4] The principle of having the moving stylus wipe the surface of the paper has been utilized by the Western Union Telegraph Company in their "Teletape" facsimile recorders.[7,8]

In measuring the electrodermal or psychogalvanic responses, a resistance in one arm of a bridge circuit is varied in a saw-tooth pattern by a motor-driven variable resistor. The subject is placed in the opposite arm of the bridge. The voltage developed at the two corners of the bridge is amplified by a 6F5 triode so as to trigger a 2050 thyratron. The thyratron pulse momentarily reduces the bias of a 6N7 dual triode which releases a flow of current through the moving contact and thus marks the Teledeltos recording paper. (See Fig. 3.) The series of dots on the continuous chart represent successive null points as the subject's resistance continues to fluctuate. In other words, each mark on the chart represents the subject's resistance at successive revolutions of the moving stylus or series of wiping contacts. By means of a decade resistance box in the arms of the bridge, the record can be expanded until 1,000 ohms is equivalent to several inches even though the subject's base level is 100,000 ohms. It should be noted that the sensitivity of the system is such that a current of no more than 50 microamperes need be passed through the subject in obtaining the records. If the subject's resistance is high, stray 60-cycle fields will introduce errors, and shielding must be used. As with the fixed stylus recording methods, referred to previously, several records can be traced simultaneously if successive electrically-isolated moving styluses are synchronized with separate sweep resistors. A record of minor skin resistance changes can thus be traced at the same time that the base level of the subject's resistance is being recorded.

This system has shown satisfactory stability in actual use and provides an inexpensive method for recording various types of autonomic responses which are characterized by relatively low-frequency fluctuations. It has the advantage over photocell recorders and servomotor systems of being able to register a shift in the trace across the full width of the recording chart without introducing the errors of devices with inertia or mechanisms which tend to "hunt" when affected by transients.

VI. ITEMIZED COMPARISON OF THE RECORDING SYSTEMS DISCUSSED ABOVE

A. FIXED-STYLUS RECORDERS

1. *Fixed-stylus Recorders Coupled to Electromechanical Pick-ups*
   - a. Minor degree of backward action (see Ref. No. 6).
   - b. Minor amount of power required to actuate pick-up.
   - c. Response frequency limited primarily by pick-up.
   - d. Inherent stability eliminates need for calibration.
   - e. Recorder itself inertialess; wide-excursion linear response.
   - f. Several independent signals can be traced simultaneously.
   - g. Various electrical instruments can be used as transducers.
2. *Fixed-stylus Recorders Coupled to Continuously-variable Pick-ups*
   - a. Backward action reduced to minimum.
   - b. Only one null point recorded per sweep cycle in bridge circuits.
   - c. Performance satisfactory but stability dependent upon trigger action of relay, thyratron, or "flip-flop" circuit.
   - d. Inertialess recorder; wide-excursion linear response.
   - e. More than one trace requires additional sweep circuits.
   - f. Construction more elaborate than for Recorder A-1, above.
3. *Fixed-stylus Recorders Coupled to Mirror Galvanometers*
   - a. Maximum current sensitivity along with unique stability. (Calibration unnecessary; "hunting" of servosystems eliminated.)
   - b. Response frequency limited by characteristic time of galvanometer.
   - c. Wide-amplitude linear response feasible.
4. *Fixed-stylus Recorders Coupled to Cathode-ray Commutator Tubes*
   - a. Backward action a minimum with common pick-ups, e.g., photocells.
   - b. Capable of recording signals of several kilocycles per second.
   - c. Amplification commonly needed. (Typical of CR tubes.)
   - d. Each signal trace requires its own commutator tube.
   - e. Bridge measurements require two commutator tubes.
   - f. Expense of construction is appreciable but not exorbitant.

B. MOVING-STYLUS SWEEP-BALANCE RECORDERS

1. *Continuously Variable Sweep Resistance*
   - a. Backward action a minimum with common pick-ups, e.g., photocells.
   - b. Marked sensitivity although inexpensive and simple to construct.
   - c. Stability satisfactory but depends upon trigger circuit.
2. *Stepwise Sweep Using Commutator System.* (Stylus moves continuously across chart but sweep resistor made up of segments. Similar to Recorder B-1 but suitable for higher signal frequencies.)

POSTSCRIPT

After this article had been submitted for publication, it was learned that Mr. Raymond S. Bark, an Electronics Engineer with the Department of Physiology and Biophysics of the University of Washington School of Medicine, has been interested in recorders with fixed styluses for several years and has built working models of a variety of such devices. Mr. Bark has also been interested in systems which are frequency-selective and voltage-selective.

Mr. Bark is of the impression that the Navy had supported an investigation of recorders with fixed styluses, generally similar to those described in this article, but ultimately discontinued further development because they appeared to be unsatisfactory as regards the particular applications under consideration at that time. On the basis of this information, it would seem likely that none of the recording systems which are discussed in the present article is particularly unique. It appears to the present writer, however, that even though such systems have been previously considered by others, these recorders have so many advantages over the ink writers now universally used that there is a need for a non-technical article so as to bring these techniques to the attention of psychologists, physiologists, and other investigators in need of better recording methods. It is anticipated that Mr. Bark will eventually publish a comprehensive monograph on direct-trace recorders.

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ACKNOWLEDGMENT

Special recognition is due Mr. George E. Price for the construction of the various paper drive mechanisms as well as the photocell sweep recorder, and for many helpful suggestions in the development of the recording systems discussed in this paper. Mr. Price is also responsible for having developed a practical vacuum-tube high-speed trigger circuit to be used with sweep recorders, as described in Ref. No. 4.

Standards *for* Electrical Measurement

By FRANCIS B. SILSBEE, Chief, Electricity Division, National Bureau of Standards, Washington, D. C.

PRECISE electrical measurements are of fundamental importance to modern science and industry. This is true not only in the communication and power fields but in many other areas where the flexibility and convenience of electrical methods have made them almost indispensable for for the measurement of non-electrical quantities. Thus, while in textbooks energy is defined simply in terms of force and length or of mass and velocity, in actual practice the heat energy of fuels and the energy output of prime movers are universally measured to high precision by electrical methods. Likewise, the basic electrical units enter into the determination of nearly all the fundamental atomic constants, as well as into daily measurements of heat, light, color, strain, acceleration, displacement, and chemical properties.

Effective application of electrical equipment and measurement methods requires uniformity to a high degree of precision in the basic electrical units. Some two billion dollars' worth of electrical machinery and apparatus is manufactured annually in this country. Were each manufacturing company to use an even slightly different value for the volt or the ohm, the apparatus made by its subcontractors would fail to function properly as a part of the final product. The result would be an impossibly confused situation, causing large financial losses to the Nation. In the communications industry, the multiplex transmission of intelligence over a relatively small number of circuits depends on the precise adjustment of capacitance, inductance, and other circuit components in such a way as to prevent the signals from straying into the wrong channels. This, again, requires precise uniformity in the measurement of the basic electrical units.

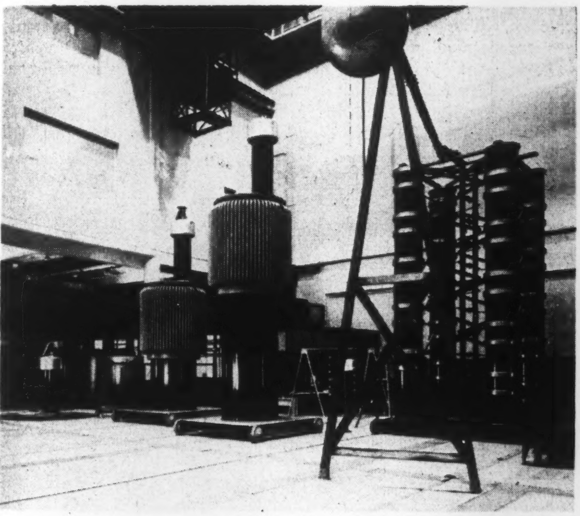
As the custodian of the national standards of physical measurement, the National Bureau of Standards has the responsibility of insuring that the units of measurement used in science and industry are constant through the years and uniform throughout the Nation. The Bureau has developed extremely precise standards of resistance and voltage whose values are established by absolute measurements that fix the relation between the electrical units and the fundamental mechanical units of length, mass, and time.[1] From these basic absolute electrical standards, the Bureau has derived other standards for all electrical measurables in use today.

Because of their technical difficulty, precise absolute measurements are carried out only in the national standardizing laboratories of a few of the larger countries. Sufficient accuracy in science and industry is obtained through accurate comparison of the secondary or working standards of other laboratories with primary standards thus calibrated. In this country such comparisons constitute the Bureau's calibration service. Each year a stream of about 2,000 high-grade electrical instruments, standard cells, and other measuring apparatus flows through the Bureau's electrical laboratories. The services performed range from the comparatively simple measurement of the emf. of a standard cell to the determination of the ratio and phase angle of a multirange current transformer at several frequencies, currents, and loads, which may require 1000 separate measurements. Among the devices submitted are potentiometers, bridges, resistance boxes, volt boxes, capacitors, inductors, multimegohm resistors, instruments and meters of all kinds, precision shunts for large currents, instrument transformers, standard magnetic test bars, magnetic test coils, and standard cells of both the saturated and unsaturated types. They come from manufacturers of electrical equipment, from public utility companies wishing to make sure that their charges are correct, from public service commissions which regulate the utility companies, and from communication laboratories, university laboratories, private commercial testing laboratories, and the many scientific laboratories of the Federal Government.

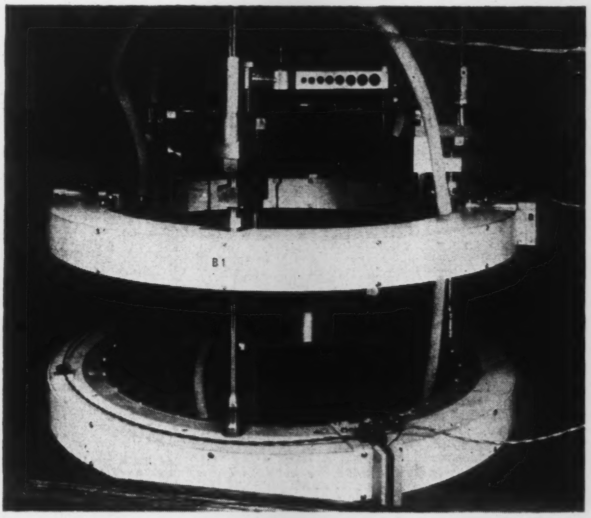
The demands of modern science and technology have made this work more and more exacting, not only as regards

(COVER PICTURE)

Calibration of a Mueller bridge in a laboratory at the NBS. If the instrument is frequently calibrated, it can measure resistance with an accuracy of a few parts in a million. A second bridge, to the left of the one under test, is used to adjust the external resistance connected to the first bridge.



Apparatus with which the NBS studies "artificial lightning" used to test high-voltage equipment. Right: the 2,000,000-volt surge generator. The large transformer in background (with smooth tank) has voltage ratings of 125,000 and 250,000 volts. It is calibrated with its primary windings in parallel and is then used with these windings in series for checking ratio of instrument transformers. The two large transformers (center), rated at 350,000 volts, serve as a supply for the measuring circuit and for other 60-cycle tests.



Coils of the current balance used at the NBS to "weigh" current for the absolute determination of the ampere. The smaller coil is suspended, coaxial with the two larger coils, from the pan of a sensitive balance. When a current flows through all three coils in series, the mechanical force between the small and the large coils is measured with the balance. From the value of this force and the mechanical dimensions of the coils, the absolute value of the ampere is computed.

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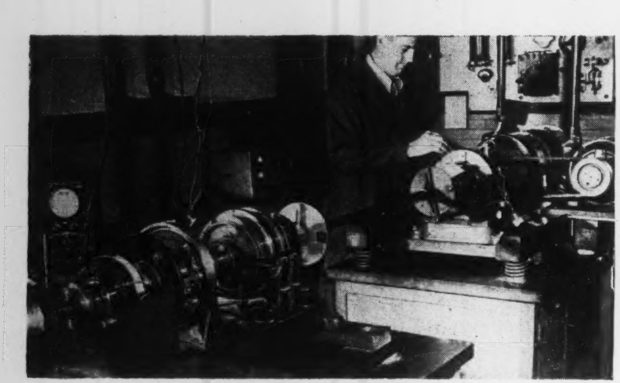
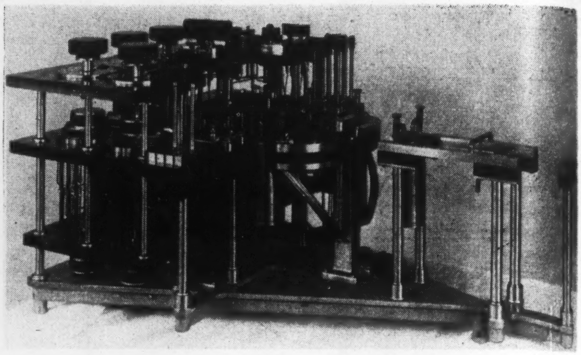
* Technical Report 1489, National Bureau of Standards.



Electrical resistance is measured at the NBS in terms of length, time, and the permeability of free space by both the mutual- and self-inductance methods. In the mutual-inductance, or Wenner, method, a group of reversing commutators, a reversing generator, and an inductor generator must be driven at a constant known rate and with fixed relative phases. The driving equipment is shown at the right, where a Bureau scientist is adjusting the timing of speed-control relays. The commutators and generators appear in the foreground. The steel box (cover removed) serves to shield a reversing commutator from the rotating magnetic field of the driving motor.



High-precision d-c. bridge used by the NBS to extend the scale of measurement of electrical resistance from the standard units maintained at the Bureau to other ranges. By successive application of the 10-to-1 ratio which the bridge provides, resistances as low as 0.00001 ohm or as high as 10,000,000 ohms can be accurately measured. In use the whole structure is immersed in a temperature-controlled oil bath to a level above that of the intermediate insulating slab so that all resistors and contacts are kept at a uniform temperature. The instrument may be connected either as a Wheatstone or as a Kelvin double bridge.

accuracy, but also in the range of values and variety of units in which measurements are made. Thus the Bureau now measures precisely currents, voltages, and resistances having values up to tens of thousands of amperes, hundreds of thousands of volts, and millions of billions of ohms. This is done with direct current, with alternating current of various frequencies up into the thousands of megacycles per second, and with surges of current lasting only a few millionths of a second.

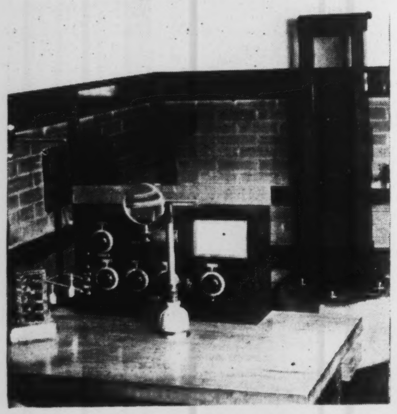
ESTABLISHMENT OF UNITS

The basis of the Bureau's standardization of electrical measurements is the establishment of values for the ohm and the ampere that bear the desired simple theoretical relation to the meter, the kilogram, and the second. However, since an electric current is by its nature evanescent, the volt, derived from the absolute ampere at the time the latter is measured, is embodied in the calibration of a group of standard cells which together with the standard resistors embodying the ohm are kept as permanent primary standards.

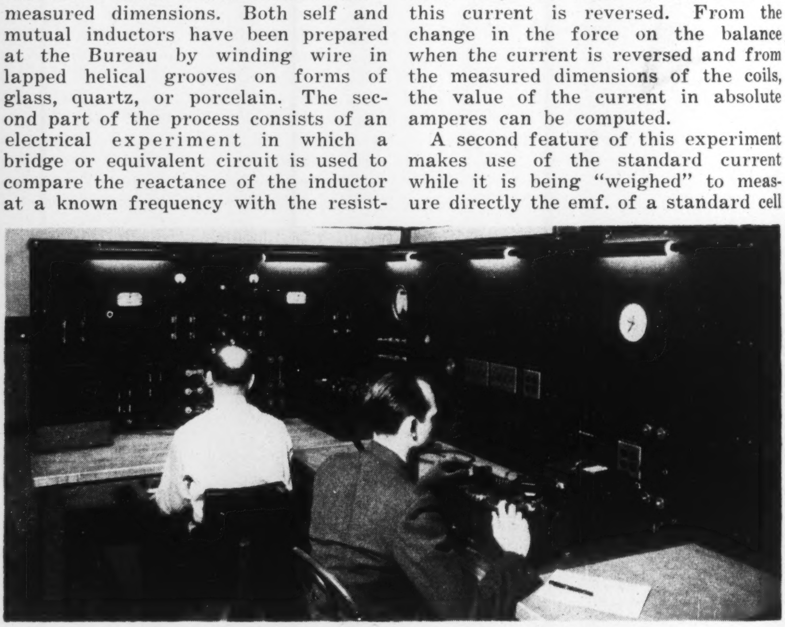
The determination of the ohm consists of two steps. The first is the construction of an inductor (either self or mutual) which is so designed that its essential dimensions can be measured mechanically with high accuracy and which is of such a shape that the inductance can be calculated from these measured dimensions. Both self and mutual inductors have been prepared at the Bureau by winding wire in lapped helical grooves on forms of glass, quartz, or porcelain. The second part of the process consists of an electrical experiment in which a bridge or equivalent circuit is used to compare the reactance of the inductor at a known frequency with the resistance to be measured. When the resistance in absolute ohms of the resistors used in the bridge circuit has been determined in this way, the absolute resistance of other standard resistors can be found by comparison.

A current is measured in absolute amperes by determining the mechanical force between two parts of the circuit in which it flows. In the center of two large fixed coils, a small coil is hung from the arm of a precision balance. All three coils carry the current to be measured, but the current in the fixed coils can be reversed. The small electromagnetic force developed by the current in the coils tends to pull the movable coil downward for one direction of the current in the fixed coils but tends to lift it when this current is reversed. From the change in the force on the balance when the current is reversed and from the measured dimensions of the coils, the value of the current in absolute amperes can be computed.

A second feature of this experiment makes use of the standard current while it is being "weighed" to measure directly the emf. of a standard cell

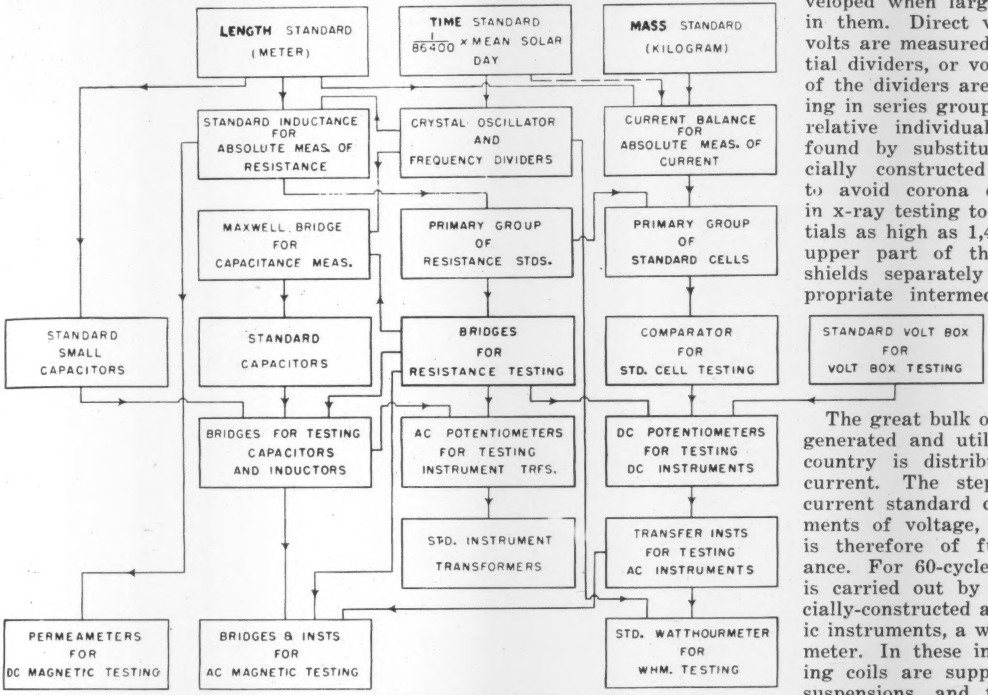


Standard astatic wattmeter (right background) used at the NBS to make the transfer from the direct-current standard cell and standard resistors to a-c. measurements of voltage, current, and power. The wattmeter is first calibrated by observing its deflection for a definite amount of d-c. power, measured by using a standard cell balanced across standard resistors, and is then used to measure a-c. power. The fixed coils are embedded in plastic blocks near the center of the frame. The moving coils are carried on suspension strips which extend the full length of the apparatus. All fixed parts are held in position by two large glass slabs. Rotation of the movable coils in the center of the frame deflects the mirror just above them so that a reflected light beam (from the source at the extreme left) moves along the scale in the foreground. Use of two movable coils serves to balance out effects due to the earth's magnetic field. The box on the table contains the adjustable series resistor for the voltage circuit.



All types of ammeters, voltmeters, wattmeters, and other electrical indicating instruments are tested in this laboratory at the NBS. The observer at the right is adjusting a potentiometer which is being used to check the calibration of a d-c. instrument in terms of a standard cell (right of potentiometer) and standard resistors (in the tank in the corner). The observer at left is setting the desired indication on the instrument under test. The switchboard provides connections to the various test circuits used for different types of instruments.

in absolute volts. This is done by arranging the standard cell so that its electromotive force is exactly balanced by the drop of potential produced in a known resistance by the standard current. The emf. of the cell is then computed by Ohm's law.


LENGTH STANDARD
(METER)
TIME STANDARD
1/86400 × MEAN SOLAR DAY
MASS STANDARD
(KILOGRAM)
STANDARD INDUCTANCE FOR ABSOLUTE MEAS. OF RESISTANCE
CRYSTAL OSCILLATOR AND FREQUENCY DIVIDERS
CURRENT BALANCE FOR ABSOLUTE MEAS. OF CURRENT
MAXWELL BRIDGE FOR CAPACITANCE MEAS.
PRIMARY GROUP OF RESISTANCE STDS.
PRIMARY GROUP OF STANDARD CELLS
STANDARD SMALL CAPACITORS
STANDARD CAPACITORS
BRIDGES FOR RESISTANCE TESTING
COMPARATOR FOR STD. CELL TESTING
STANDARD VOLT BOX FOR VOLT BOX TESTING
BRIDGES FOR TESTING CAPACITORS AND INDUCTORS
AC POTENTIOMETERS FOR TESTING INSTRUMENT TRFS.
DC POTENTIOMETERS FOR TESTING DC INSTRUMENTS
STD. INSTRUMENT TRANSFORMERS
TRANSFER INSTS FOR TESTING AC INSTRUMENTS
PERMEAMETERS FOR DC MAGNETIC TESTING
BRIDGES & INSTS FOR AC MAGNETIC TESTING
STD. WATTHOURMETER FOR WHM. TESTING

Block diagram showing steps used by the NBS in deriving precise values for all the electrical units from the basic mechanical units of length, mass, and time. It also shows how the Bureau applies these electrical standards to the testing of electrical measuring apparatus and standard magnetic specimens.

A group of twenty-five standard cells and a group of ten carefully-constructed 1-ohm standard resistors serve to preserve the values of the volt and of the ohm from day to day and from month to month. The various members of each group of standards are intercompared at intervals of a few months and, as long as their relative values are constant, it is assumed that the absolute mean value of the group has also remained constant. If an individual standard is found to have drifted relative to the others in its group by a significant amount since the previous intercomparison, it is rejected and replaced by another standard which has a good record of performance. The process of comparing a resistor with the standard mutual inductor is so convenient that it is frequently used as an independent check on the constancy of the group of standard resistors. However, the mechanical measurement of the dimensions of the inductors and of the current balance is so tedious and time-consuming that this experimental work is carried through only once in a decade as the final check on the constancy of both types of standard.

From the standard ohm and the volt thus maintained at the Bureau, the other electrical and magnetic units are derived by a variety of experimental procedures. The farad is precisely obtained by charging and discharging an air capacitor at a known rate in a Maxwell commutator bridge. The henry is determined by comparison with capacitors and resistors in a Maxwell-Wien bridge. The ampere is reestablished, when desired, by measuring with a potentiometer the drop it produces in a known resistance. The ampere and the volt are combined to give the watt, and the joule and kilowatt hour are derived by maintaining a known number of watts in a circuit for a measured length of time. The gilbert and the oersted are computed from the number of ampere-turns used in magnetizing a magnetic test specimen in a permeameter of known geometry. The gauss and maxwell are obtained from the deflections of a ballistic galvanometer which, in turn, is calibrated by reversing a measured current in a known mutual inductor.

Extension of Ranges

The extension of the scale of measurement of any of the electrical measurables to other ranges is based, in large part, upon the establishment of a ten-to-one ratio in a special highly-accurate bridge. By successive application of the ratio, resistances as low as 0.00001 ohm or as high as ten million ohms can be accurately measured. Still higher resistances, up to 10^{15} ohms, are measured by more complex methods, such as the determination of the rate of accumulation of charge in a known capacitor. Inductance and capacitance measurements are extended over wide ranges by means of ratio arms of known resistance ratio. However, determination of standard capacitances below 1 micromicrofarad is based upon an independent set of measurements involving the construction of air capacitors of such shapes that their capacitance can be computed precisely from their dimensions.[2]

Direct currents as high as 10,000 amperes are measured with a potentiometer and standard resistors of low value so constructed that their temperature and resistance are not affected by the considerable heat developed when large currents are used in them. Direct voltages up to 1500 volts are measured by means of potential dividers, or volt boxes. The ratios of the dividers are derived by connecting in series groups of resistors whose relative individual values have been found by substitution methods. Specially constructed resistors, shielded to avoid corona discharge, are used in x-ray testing to measure d-c. potentials as high as 1,400,000 volts. In the upper part of this range additional shields separately maintained at appropriate intermediate potentials are required.

The great bulk of the electric energy generated and utilized throughout the country is distributed as alternating current. The step from the direct-current standard cell to a-c. measurements of voltage, current, and power is therefore of fundamental importance. For 60-cycle work, the transfer is carried out by means of two specially-constructed astatic electrodynamic instruments, a wattmeter and a voltmeter. In these instruments the moving coils are supported by taut strip suspensions, and the position of the moving coils is indicated by a spot of light on a scale at a distance equivalent to a pointer 13 feet long. The wattmeter has been carefully compared both with a quadrant electrometer and with the loss in a capacitor which had been tested in a Schering bridge; such measurements have established the accuracy of the two electrodynamic instruments at frequencies up to 3000 cps. Directly or indirectly, the accuracy of practically all the a-c. instruments used in the transmission of electric energy depends on these two standard instruments. For tests of ammeters and voltmeters at 400 cps. and above, transfer circuits employing thermocouples are also used.

In commercial practice the range of alternating current is extended upward from five amperes by means of calibrated current transformers. Thus, an important part of the Bureau's calibrating service consists in the calibration of standard current transformers which, in turn, are used by manufacturers and electric utility companies to calibrate their working transformers.

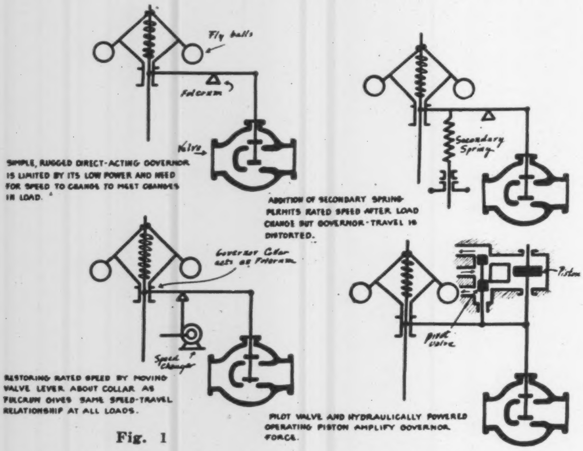
Continued on page 80

POWER PLANT CONTROLS

By B. F. HEYE, Results Engineer, Central Power and Light Company, Corpus Christi, Texas

INTRODUCTION

THE small and relatively simple power plants of yesteryears have grown into the mammoth and complex power stations as we know them today. The early power station consisted of a generator, either alternating or direct current, driven by a steam engine exhausting to the atmosphere. The steam was furnished by a simple type of boiler consisting of tubes connected to a steam reservoir. The fuel requirement was met by manpower—usually coal being shoveled into the furnace on a set of grates.



SIMPLE, RUGGED DIRECT-ACTING GOVERNOR IS LIMITED BY ITS LOW POWER AND NEED FOR SPEED TO CHANGE TO MEET CHANGES IN LOAD.

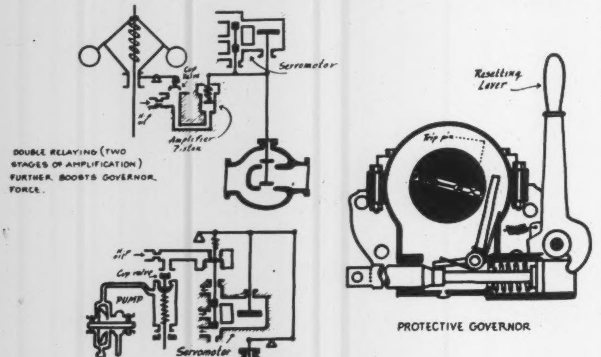
ADDITION OF SECONDARY SPRING PERMITS RATED SPEED AFTER LOAD CHANGE BUT GOVERNOR-TRAVEL IS DISTORTED.

RESTORING RATED SPEED BY MOVING VALVE LEVER ABOUT COLLAR AS FULCRUM GIVES SAME SPEED-TRAVEL RELATIONSHIP AT ALL LOADS.

PILOT VALVE AND HYDRAULICALLY POWERED OPERATING PISTON AMPLIFY GOVERNOR FORCE.

Fig. 1

With this type of installation the only instruments used were the steam pressure gage on the boiler and an ammeter and voltmeter on the switchboard. The electric switches were of the open knife type, manually operated, inasmuch as the voltages employed were much lower than they are at the present time. At this time the electric service sold as "six-bits" per "light drop" which amounted to a good deal considering that salaries of $30.00 per month were considered very good.



DOUBLE RELAYING (TWO STAGES OF AMPLIFICATION) FURTHER BOOSTS GOVERNOR FORCE.

PROTECTIVE GOVERNOR

SPEED-RESPONSIVE ELEMENT MAY BE SHAFT-DRIVEN IMPELLER INSTEAD OF FLYBALLS

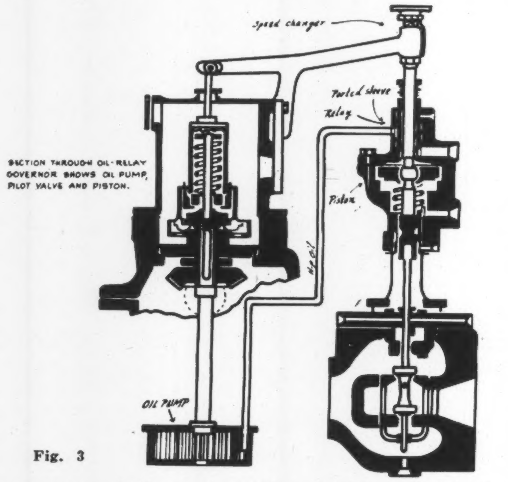
Fig. 2

In most installations the height of water in the boiler drum or steam reservoir was more or less a guess and thus it was not uncommon to hear of firemen taking unexpected flights through the atmosphere due to boiler explosions. One unique method used for ascertaining the water level in the steam reservoir was dashing a dipper of cool water, or a pail of beer which was quite cheap in those days, against the side of the boiler drum. The water level was ascertained as a dividing line between that portion of the liquid which evaporated more rapidly than the other.

Station controls were very simple and not too reliable—resulting in many untimely shut-downs. The voltage was controlled manually by the operation of a rheostat in the generator exciter field circuit, and the steam pressure was manually controlled by the fireman shoveling more or less coal in the boiler furnace.

The lack of proper instrumentation and control caused frequent power plant shut-downs, and thus a great deal of unfavorable comment from our No. 1 controller—the customer.

Freedom of enterprise has made the modern power stations of today far removed from those of fifty years ago. The high voltage (13,800 volts and above) generators are driven by high pressure (400 to 2,000 psi.) steam turbines rotating at speeds of 1800 and 3600 rpm. with capacities as high as 210,000 kwh on a single steam driven unit.



SECTION THROUGH OIL-RELAY GOVERNOR SHOWS OIL PUMP, PILOT VALVE AND PISTON.

Fig. 3

These power stations are equipped with a multitude of instruments, efficient machinery, and automatic controls for furnishing our customer an adequate supply of cheap electric service. In passing through a modern power plant a visitor is quickly impressed by the many and various types of controls employed to accurately accomplish certain definite purposes.

GOVERNORS

Perhaps the oldest power plant control is the one used for maintaining a constant speed on the prime mover driving the generator. This controller commonly known as a governor was developed in the early states of steam engine operation and has been constantly improved upon from the simple fly-ball type of the "Gay 90's" to the complicated hydraulic types used on the high speed turbines of today, each change made being for the purpose of controlling the speed of a given prime mover more accurately.

Nearly all governors depend for their action upon centrifugal force, generally a spring. With an increase in speed, this controlling force is overcome and the masses move outward, which motion is transmitted to valves supplying the prime mover with its working fluid. In small machines, the governor acts directly upon the energy regulating valve or valves, while in large machines the governor moves small controlling valves admitting fluid under pressure into operating cylinders actuating the main steam admission valves.

The various types of governors are as follows:

1. Conical pendulum governor
2. Loaded governor

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* Presented at the fifth symposium on "Instrumentation for the Process Industries," Texas A & M College, College Station, Texas, Oct. 11-13, 1950.

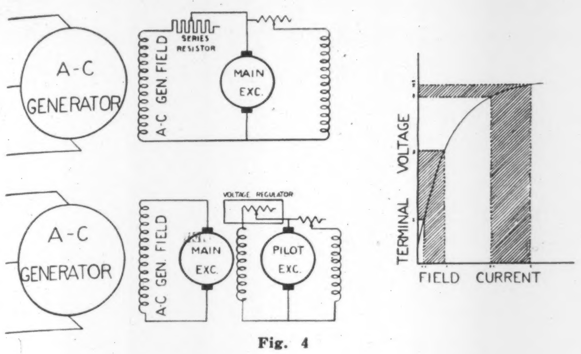

A-C GENERATOR
A-C GEN. FIELD
SERIES RESISTOR
MAIN EXC.
VOLTAGE REGULATOR
PILOT EXC.
TERMINAL VOLTAGE
FIELD CURRENT

Fig. 4

3. Crossed-arm governor
4. Spring-loaded governor
5. Shaft governor
6. Hydraulic governor

Figs. 1, 2 and 3 illustrate some of the various types of governors.

VOLTAGE REGULATORS

Perhaps the next power plant control developed was the voltage regulator. As one may suspect, some power plant controls were originally developed by power plant operators who were not as energetic as they should have been and thus developed a means for doing their work while they were otherwise occupied. Incidentally, these apparatuses ultimately resulted in giving better electric service, and also protection to the power plant equipment.

This appears to be particularly true in regards to the voltage regulator since in the early days the switchboard operator was constantly required to adjust the current in the generator exciter field by the manual operation of a rheostat. During certain times of the day these changes kept the switchboard operator very busy and thereby deprived him of the time necessary to execute his other duties. This dilemma resulted in some ingenious switchboard operator developing an apparatus which automatically took care of any fluctuations in voltage. This apparatus rendered better electric service by eliminating the slowing down and speeding up of various electric motor driven equipment and likewise eliminated the bilious feeling encountered while attempting to read the evening paper under the flickering electric lights.

As is the case in all industrial development, the original simple voltage regulators have gone through a stage of evolution and development through the years. As power circuits became more complicated and the transcontinental electric transmission systems came into existence the problem of voltage control became complicated.

Three types of modern power plant voltage regulators are illustrated. While the circuits appear complicated, the principle of varying the current in the exciter-generator field circuit remains the same. The additional circuits and the added equipment such as the pilot exciter are used for better voltage control and protection during normal as well as adverse operating conditions. The use of the pilot exciter with the alternator main exciter is explained in the following statements. (Fig. 4).

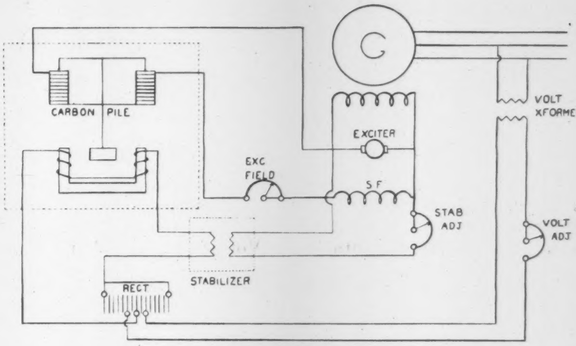

C
CARBON PILE
VOLT XFORMER
EXCITER
EXC FIELD
SF
STAB ADJ
VOLT ADJ
STABILIZER
RECT

Fig. 5. Carbon-pile voltage regulator.

A self-excited d-c. generator must be operated past the knee on the saturation curve for stable operation. At this point on the curve a change in field current causes little change in voltage.

A separately excited generator would be stable on any position of the saturation curve because a change in voltage would not cause a change in its field current.

A self-excited exciter used to excite an alternator must operate past the knee on the saturation curve for stabilization.

Series resistors must be used to change excitation on alternator fields in order to change alternator output voltage. When this is done a considerable I^2R loss and heat generation in the series resistor is encountered. Also the sliding contacts in this circuit cause a large number of maintenance problems. In order to eliminate these difficulties a separate exciter (called the pilot exciter) is used to excite the exciter.

A pilot exciter always operates past the knee of the saturation curve and thus maintains stable voltage. With this characteristic, the main exciter may operate on any position of the curve and voltage of the alternator may be varied easily by changing the field current on the main exciter, thus avoiding the large I^2R loss and maintenance problems.

Three types of voltage regulators are described as follows:

I. *Carbon Pile Regulator* (Fig. 5)

A. Operation—A change of pressure on the carbon pile changes the electrical resistance of the pile varying the current flow through the exciter field, thus changing the output voltage of the exciter and thereby the output voltage of the alternator.

B. Voltage Regulation—If output voltage of the alternator decreases, the secondary voltage of the voltage transformer decreases and rectified voltage will decrease, chang-

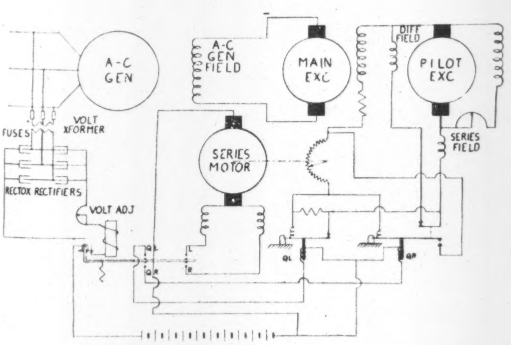

A-C GEN
A-C GEN FIELD
MAIN EXC
DIFF FIELD
PILOT EXC
VOLT XFORMER
FUSES
SERIES MOTOR
SERIES FIELD
RECTOX RECTIFIERS
VOLT ADJ
QL
QR
L
R

Fig. 6. Balanced-beam voltage regulator.

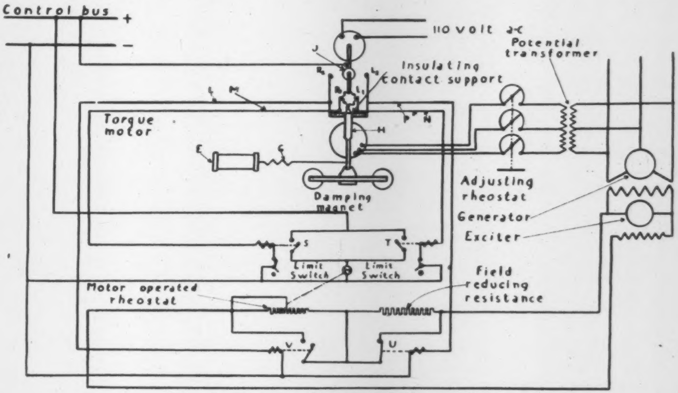

Control bus
+
−
110 volt a-c
Potential transformer
J
Insulating contact support
Torque motor
H
E
G
P
N
L
M
Damping magnet
Adjusting rheostat
Generator
Exciter
S
T
Limit Switch
Limit Switch
Motor operated rheostat
Field reducing resistance
V
U

Fig. 7. Torque voltage-regulating system.

ing the pull on the carbon pile and increasing current flow through the field of the exciter, thus raising the alternator output voltage.

C. Stabilizer Action—The stabilizer operates through the use of a transformer. If the voltage of the exciter changes, the current flow through the transformer will change; and the rectified current in the secondary of the transformer will be in such a direction as to resist any further change in exciter voltage. Thus it is easily seen that the stabilizer acts as a damper in the system, resisting any rapid changing in voltage.

D. Disadvantages—Voltage control is accomplished by single phase indications and may not necessarily be correct for an unbalanced load. Also adaptable, as a rule, to machines of 5000 kw or less that do not have a pilot exciter.

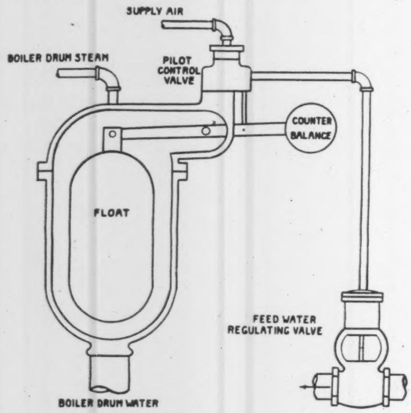


Fig. 8. Intermittent-type feed water regulator.

II. *Balanced Beam Regulators* (Fig. 6)

A. Operation—The three-phase voltage of the alternator is rectified and delivered to a solenoid whose field normally maintains the beam in a balanced position. Should the voltage increase or decrease a slight amount, the L or R contacts on the beam will close. Should the voltage increase or decrease a large amount, the QL or QR contacts will close.

B. Action For Small Voltage Changes—Should the beam close contact L the series motor will move in such a direction as to increase the resistance of the field rheostat, lowering the output voltage of the main exciter.

C. Action for Large Voltage Changes—Should the voltage of the alternator decrease greatly as caused by a short on the line, etc., the QR contacts will close, closing the QR relay. The QR relay will close two contacts, shorting out the motor-driven field rheostat, increasing the current flow through the main exciter shunt field. The QR relay will also open two other contacts opening up the main exciter differential field. Should the voltage of the alternator increase in a large amount as if the machine was tripped off the line, the QL relay would open the contacts and place a series resistor in series with the motor-driven resistor, thereby decreasing the alternator voltage.

III. *Torque System* (Fig. 7)

A. Operation—A torque proportional to the output voltage is obtained by the use of a three-phase motor whose rotor is allowed only a few degrees movement. Normally the torque of the rotor is balanced by the use of a spring. Should the output voltage rise, the torque of the motor will overcome the tension of the spring and contact L_1 will close. If the output voltage raises a large amount the contact L_2 will close.

B. Action for Small Changes—For small variations in voltage only contacts L_1 or R_1 will be closed, and the action of these contacts activate the motor changing the motor-operated field rheostat, changing the current flow through the shunt field and thereby raising the alternator voltage.

C. Action for Large Voltage Changes—For large variations in voltage contacts R_2 or L_2 will be closed, activating relay V or U and either shorting out the motor-operated field resistance or placing a field-reducing resistance in series with the motor-operated field rheostat.

As can be seen from the sketches, automatic voltage regulation is really accomplished by varying the amount of current delivered to the generator field by the main exciter. The various systems mentioned attempt to do this in several ways, and also in such ways that the apparatus is very sensitive to voltage fluctuations and quick to compensate for these variations.

Boiler Feed Water Regulators

The fact that the switchboard operator had developed this gadget for controlling voltage changes automatically and, moreover, had a governor on his prime mover to take care of any speed changes due to load fluctuations, aggravated the power plant fireman grievously. Because of his aching back from meeting fuel requirements and enduring a stiff neck trying to see the water level in a dirty gage glass on the boiler drum, he lived in a foul humor most of the time.

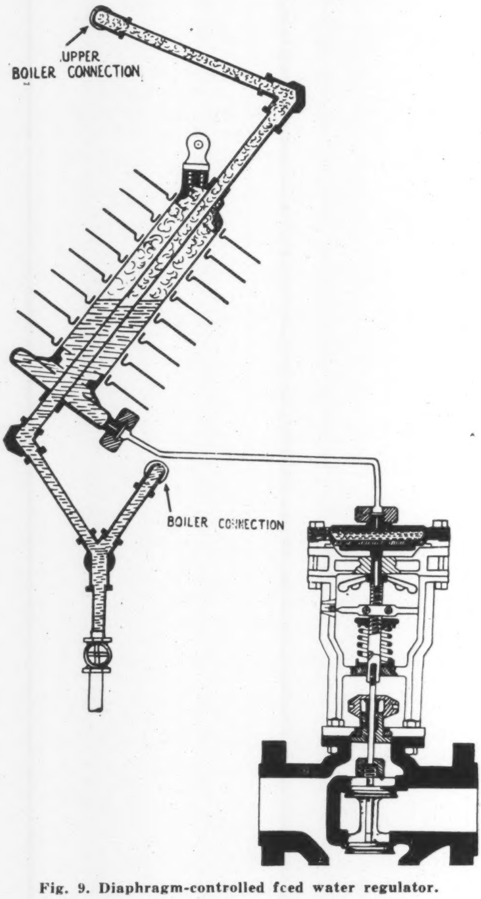


Fig. 9. Diaphragm-controlled feed water regulator.

The proper feedwater flow to a boiler has always been of concern to the fireman, even though in days gone by he had talked the boss into placing a man in charge whose sole duty was to be certain that there was always a sufficient supply of water in the boiler. As humans often err, the fireman knew that if the "water tender" became lax and a boiler explosion resulted it would be he who would be wearing wings and playing a harp in Paradise.

Some controls have been developed by a lazy body energizing an alert mind. While other power plant controls have been developed because of fear and the desire for safety. It appears because of the latter there came into existence, or was developed, the feed water regulators known today, as well as the more recent development of the boiler feed water flow control by means of regulating the centrifugal feed pump speeds by hydraulic or magnetic coupling drives.

It is obvious that the flow of water to a boiler over a period of time must be equal to the amount of steam flow from the boiler plus boiler blowdown requirements. Various devices automatically controlling the required flow of water to a boiler are known as feed water regulators. Feed water regulators are classified as intermittent and continuous types.

The intermittent type is used on very small boilers and varies the water fed to the boiler by means of supplying energy to the boiler feed pump intermittently. The impulse controlling the energy supply is received from a float chamber properly connected to the side of the boiler drum. Attached to the float in this chamber is a pilot valve arrangement which actuates a water flow-control valve and a valve or electric switch supplying energy to the boiler feed pump drive. By properly setting the levers actuating the pilot valves, the high and low water levels are set, resulting in an "on" and "off" feed water flow. This type of boiler water regulator is rarely used today (Fig. 8).

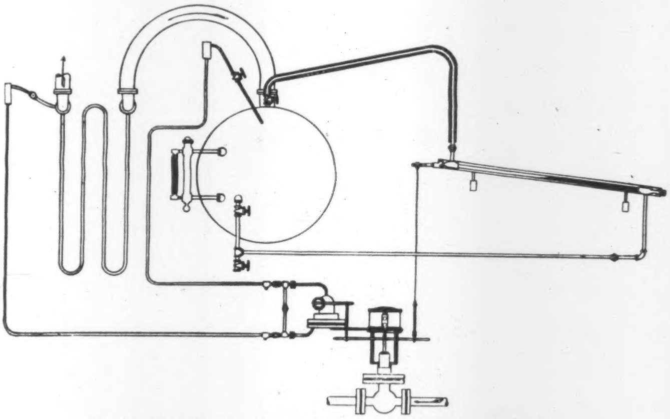


Fig. 10. Two-element thermostatic-type feed water regulator.

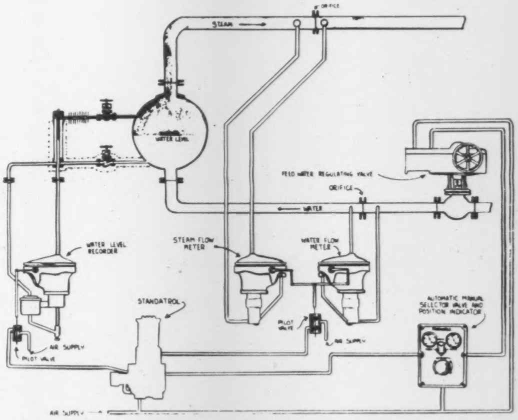


Fig. 11. Three-element air-operated type feed water regulator.

The continuous-flow feed water regulators more commonly used at present are the types which throttle the flow of boiler feed water from a centrifugal boiler feed pump by means of a thermohydraulic regulator or thermostatically controlled feed water regulating valve.

The thermohydraulic regulator usually consists of a primary element (called a generator), a diaphragm- or bellows-controlled feed water regulating valve, and flexible tubing connecting the two together (primary element and water valve). (Note Fig. 9)

The operation is as follows: The heat of the steam in the space above the water level in the control pipe is transmitted through the walls of the pipe to the water in the chamber surrounding the control pipe causing a portion of the water to evaporate into steam. The pressure of this vapor is transmitted through the water through the flexible tubing and on to the diaphragm or bellows in the top of the feed water regulating valve and causes the valve to open. When the water level in the boiler and thus in the control pipe is lowered, the amount of water evaporated in the chamber is increased because more heat is transmitted through the walls of the pipe to the water in the chamber. The increased evaporation exerts a greater pressure on the diaphragm or bellows, causing the control valve to open and thus feed more water to the boiler.

When the water level in the boiler rises higher than normal, the water in the central pipe is also raised and thereby causing less heat to be transmitted to the water in the generating chamber. This causes some of the steam in the chamber to be condensed, thus relieving the pressure on the diaphragm or bellows and resulting in the partial closing of the water regulating valve by means of the valve spring until normal water level is reached. Radiators are provided on the outside of the generator to make the steam in the generating chamber condense more rapidly.

The thermostatically-controlled feed water regulator operates a great deal like the thermohydraulic type. The regulating valve is operated by means of impulses received through the expansion or contraction of a tube set at an incline alongside the boiler drum such that the center of the tube is at the same elevation as the desired water level in the boiler drum. Such a feed water regulating system is shown in Fig. 10.

In both types of regulators discussed, the impulses received from the primary element, namely the thermostatic tube or generating chamber, can be transmitted to the water controlling valve by means of levers, pilot-operated pneumatic, liquid or electric transmission systems. The feed water regulators thus discussed operate solely on boiler water level and are called single element controllers.

As the water storage capacity of many new type boilers has been greatly reduced, the sizes of the drums have been correspondingly decreased and smaller high-pressure drums are now being used. Therefore a feed water regulator that is dependent upon water level alone for its operation will not respond quickly enough for good operation at high steaming rates. Under high steaming rates the "swell" of the water due to a greater number of steam bubbles contained therein raises the water level considerably.

It has been found that the "swell" in boiler water from no load to a load of 350,000 lbs./hr. evaporation is approximately 18 percent and amounts to a 30-in. rise in water level from normal. From this it can be seen that although a large amount of water leaves the boiler drum (in the form of steam) the water level will not respond rapidly enough to immediately replace the water required for the extra steam flow.

In recent years feed water regulators have been manufactured with two elements of control—that is a steam flow element has been added to the primary water level element to vary feed water flow in accordance to seam demand on the boiler. Regulators of this type measure the steam flow which augments the primary level control to give a more rapid change in feed water flows with varying steam flows. The steam flow elements usually operate through a pilot device using the usual transmission systems for transmitting the impulses to the main feed water regulating valve. Adjustment can be made for the ratio of steam flow control to the level control element. A two-element flow control system is shown in Fig. 10.

More recently a third element has been added—water flow. In this type of regulator the primary level control and the steam flow element are supplemented with a water flow element. This device regulates the flow of water in accordance to the steam flow, water flow, and of course, with the primary element (or level element) having the master control. (Note Fig. 11) The three-element feed water regulator has many advantages over the other types and is being used very extensively.

In some high pressure installations, feed pumps are driven by prime movers through hydraulic couplings. Power and

Continued on page 55

Some Developments *in* Electronic Instrumentation Including Process Control

By **W. T. MARCHMENT**, **Evershed & Vignoles Ltd., Chiswick, London W4, England**

INTRODUCTION

DURING the war years the widespread use of electronics in connection with servomechanisms gave an added stimulus to the application of electronics in solving measurement and control problems in industry. The enormous demand of the Services also resulted in the availability of a wide range of reliable components. The advantages to be gained by the use of electronics and electrical measuring circuits in instrumentation are such as to make them of ever increasing appeal to the user.

Advantages. These may be enumerated as follows:

(a) High sensitivity in detecting physical or electrical changes.

(b) High speed of response.

(c) Extreme flexibility of electrical apparatus.

(d) Transmission without signal lags.

(e) Summation, subtraction, division and multiplication may be achieved without complicated mechanical linkages.

(f) The three functions in a Process Controller, viz. proportional, integral and derivative actions, can be adjusted independently without the one affecting the other.

(g) All controller adjustments can be made by accurately repeatable wire-wound voltage dividers. This makes for complete flexibility in layout, and adjustments may be made from any position on a control desk.

(h) The Controller Amplifier Trays may be plugged into racks effecting a saving in space and forming readily replaceable units.

In this Paper the Author refers to some developments in electronic instrumentation with which he is familiar.

Equipment for Process Control. In the developments about to be described the equipment is in three sections:

(a) The measuring and transmitting unit for detecting and transmitting level, flow, pressure etc.

(b) The controller providing proportional, integral and derivative control functions.

(c) The electropneumatic relay or valve positioner.

Transmitting System. A current system is used for transmitting signals from the measuring units and the principle of operation is shown diagrammatically in Fig. 1. In this system a thermionic tube is used as a variable resistor to obtain a variation of plate current from 0 to 30 ma. proportional to the condition being measured by the originating movement. The transmitter is essentially a torque-balancing device in which the torque exerted by the originating movement is balanced by the torque of a coil through which the plate current passes. The pointer of the originating movement carries a coil which operates in the annular gap of a pot shaped magnet. This coil is in the cathode circuit of the thermionic tube, the circuit being completed through indicators, recorders and controllers to the negative side of a bridge rectifier. A contact connected to the grid is also carried on the pointer and floats between two fixed contacts providing positive and negative grid bias voltage.

For originating movements such as pressure gages, or where the torque obtainable from the coil would be insufficient to balance that of the originating movement, a spring link is interposed between the coil and the movement.

Principle of Operation. When in balance the current in the circuit is proportional to the condition being measured and the grid contact is in a neutral position between the two fixed bias contacts. The voltage on the grid is maintained substantially by a storage capacitor between grid and cathode. Any unbalance created by a change in the

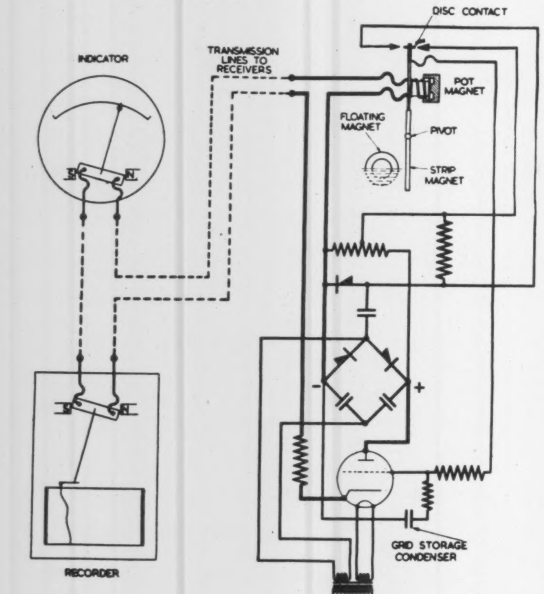
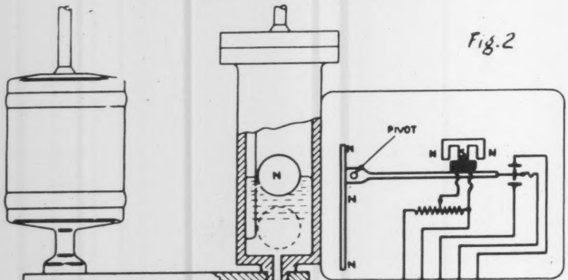


Fig.1

PRINCIPLE OF OPERATION OF EVERSHED 'ROLLFLOW' METER

Fig.2



EVERSHED ELECTRONIC REPEATER SYSTEM
DIAGRAM OF CONNECTIONS OF
FLOW TRANSMITTER (HIGH RANGE)

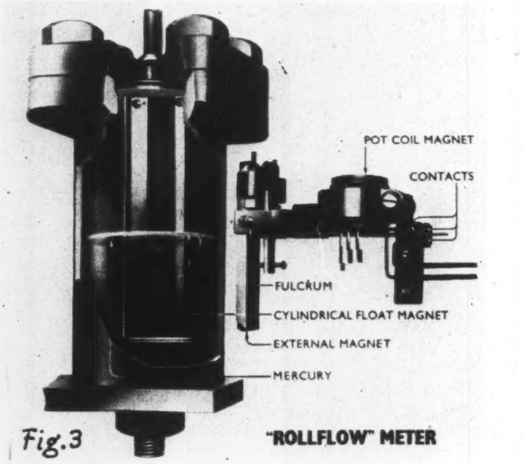


Fig.3 "ROLLFLOW" METER

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*Presented at fifth symposium on "Instrumentation for the Process Industries," Texas A&M College, College Station, Texas, Oct. 11-13, 1950.

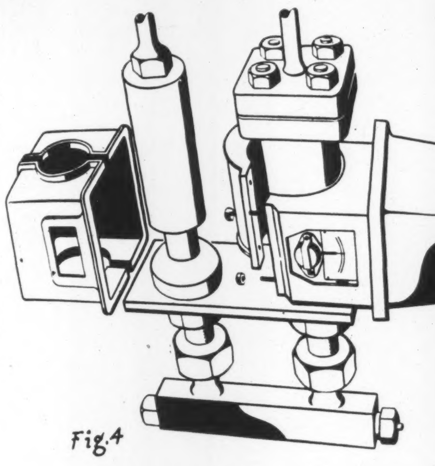


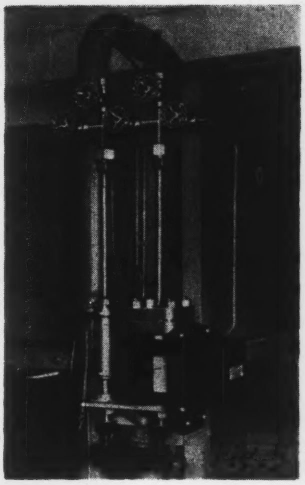
Fig. 4

condition being measured causes the grid contact to touch the appropriate bias contact and so alter the plate current to bring the system again into balance. The accuracy of transmission is independent of large variations in supply voltage, line resistance, frequency, and electron-tube characteristics.

Indicators, Recorders and Integrators (Totalizers). Simple milliammeter movements are used for Indicators and Recorders, and milliampere-hour meters where integration or totalization is required. These instruments may be inserted in any position in the series transmitting circuit. The total external loop resistance including indicators, recorders, etc., may be up to 1000 ohms, which permits transmission over a considerable distance.

Application of Transmitters. Various applications of the system shown in Fig. 1 will now be described including Process Control.

Flowmeters (High-pressure Differential). The principle of operation is shown in Fig. 2. The flowmeter consists of a stainless steel manometer having a measuring and range tube. Inside the measuring tube is a cylindrical floating magnet polarized along its axis and housed in a stainless steel cage. A pivoted strip magnet is mounted externally and polarized across its width in such a direction that the two magnets are repelled. An arm attached to the strip magnet carries a coil which operates in a pot magnet as previously described in Fig. 1. At zero differential the cylindrical magnet floats on the mercury at a level to produce a repelling force through the fulcrum of the pivoted strip magnet. At this level no turning moment exists and the current required to balance is zero. With a change in mercury level the cylindrical magnet rolls to a new position and a turning moment is produced due to the repelling force being away from the fulcrum point. The coil arm deflects by reason of the balance being disturbed and the appropriate grid contact is made. The plate current is thus varied until the torque exerted by the pot coil balances that due to magnetic repulsion. The current in the coil is therefore proportional to the differential head.



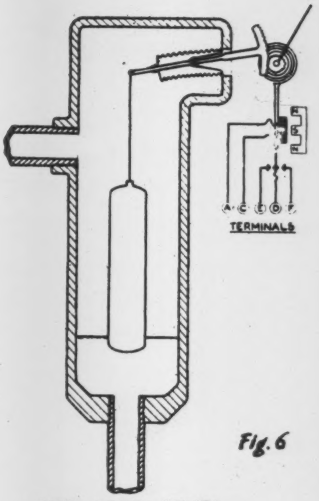


Fig. 6

DISPLACER LEVEL TRANSMITTER

Differential Manometer. The manometer is designed for a working pressure of 1500 psi. and is fabricated in stainless steel. Fig. 3 shows a sectional photograph of the measuring tube of the manometer and the external magnet assembly. Zeroing is effected by raising or lowering the external unit and an adjusting screw is provided for this purpose. Fig. 4 shows an exploded view to illustrate how the external unit is clamped on to the measuring tube. A mechanical indicator is provided to give an indication of flow locally, and this is coupled magnetically to the cylindrical magnet float. The complete flowmeter is shown in Fig. 5.

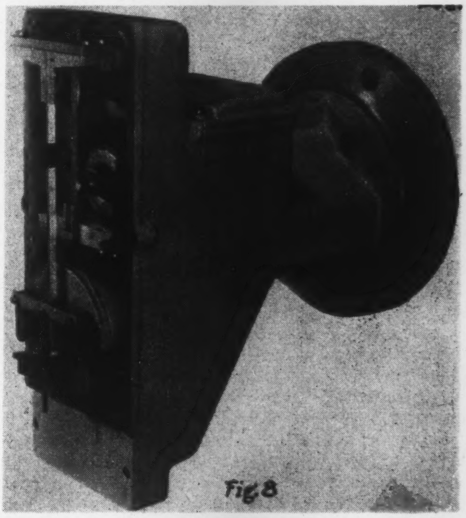


Fig. 8

Level Transmitter. A displacer type level detecting unit is shown diagrammatically in Fig. 6. The change in apparent weight of the displacer due to a rise or fall in liquid level is measured by a calibrated spring fitted externally. A pivoted lever to which the displacer is connected operates through a bellows seal and winds up a small spring so that its torque is proportional to level. This torque is balanced by that of a pot coil and a current transmitted by the method previously described and shown in Fig. 1. A displacer unit with transmitter is shown in Fig. 7.

Tank Contents Gage. Where a measurement of tank con-

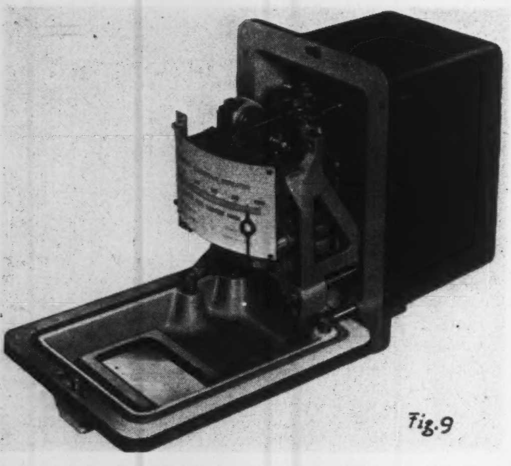


Fig. 9

tents is required and it is not permissible to use floats or moving parts, the hydrostatic type of gage is used. A transmitting gage is shown in Fig. 8 in which the transmitted current is proportional to the hydrostatic head. In this unit the force on a flexible diaphragm due to the static head of liquid in a tank is opposed by the force of a coil carrying current. The current is derived from a transmitter circuit as described in Fig. 1. In this unit the coil operates in the annular gap of a large pot-shaped magnet through a system of compound levers, and the leverage can be adjusted to suit various ranges. With this type of gage the indicators are usually calibrated in terms of weight.

Pressure Transmitter. A typical pressure-transmitting unit shown in Fig. 9 is designed to accommodate Bourdon, bellows, or diaphragm pressure elements.

Gas Flowmeter. The measurement of gas flow is often required in mains where the static pressure is low and it is therefore necessary to use measuring apparatus capable of operating from differential heads of about 2 inches water gage. Fig. 10 shows a flowmeter suitable for measuring differentials down to 2 inches water gage. The principle of operation is similar to the one previously described and shown in Fig. 2. In this case kerosene is used instead of mercury for the manometer and the magnet is therefore supported by a metal float.

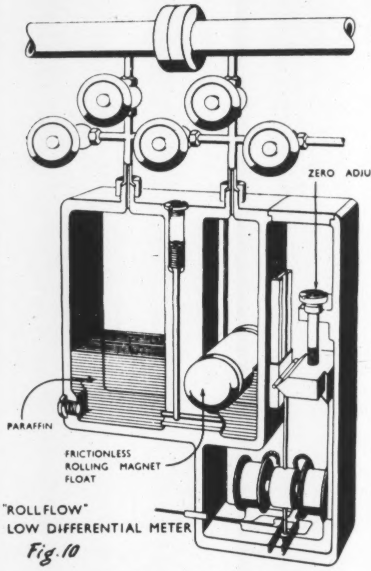
As integration is required for most gas flow measurements the transmitted current has to be proportional to flow. To achieve this the current passes through fixed coils connected in series with a moving coil. Therefore the torque opposing that due to the magnet float will vary with the square of the current. Thus the current will be directly proportional to the flow.

Safety Precautions. The transmitting circuits just described are in practice divided into two parts: *The Transmitter,* comprising the originating movement or primary element with pot coil assembly; *The Power Pack,* comprising the transformer, tube and rectifier. The transmitter and its connecting wires to indicator and controller etc., are "intrinsically safe," and a certificate of "intrinsic safety" has been granted by the Inspector of Factories in the United Kingdom. The certificate is issued for apparatus or circuits incapable of causing an explosion of prescribed inflammable gases or vapors, resulting from sparking during normal working, breaking of line current, or a short circuit across lines. The certificate covers pentane vapors representing hexane, heptane and acetone, and is issued only after the apparatus has been subjected to tests. The power pack is housed in an explosion-proof case and forms part of the controller about to be described.

ELECTRONIC PROCESS CONTROLLER

The controller about to be described will be referred to as a three term controller having proportional, integral or automatic reset, and derivative functions.

General Description. Fig. 11 is a functional diagram of a three-term controller and, for the sake of simplicity, four tubes are shown whereas in practice three tubes are used, the plates of tubes Nos. 22 and 15 being in one envelope. For convenience of identification the various units are numbered on the diagram.



"ROLLFLOW" LOW DIFFERENTIAL METER

Fig. 10

Transmitter No. 1. This unit has been referred to previously and provides a current of 0-30 milliamperes to the controller, proportional to the measured condition and will be referred to as the measuring current.

Proportional Unit No. 14. The transmitted measuring current passes through one coil of a double-coil movement operating in the field of a permanent magnet. The other coil is in the plate circuit of tube No. 15 and in series with an electropneumatic relay No. 8 coupled to a diaphragm-operated control valve. This relay (to be described later) produces an air pressure proportional to the measuring current.

The double-coil movement carries a shutter which controls the amount of light to two phototubes of a photoelectric bridge circuit. With unequal currents in the two coils, the movement deflects and the bridge is unbalanced. The out-of-balance voltage is applied to the grid of tube No. 15 and the storage capacitor connected between grid and cathode. The plate current is thus varied until the torques exerted by the two coils are equal and the bridge is again balanced. It will be seen, therefore, that the output current I_0 to the electropneumatic relay is proportional to the measuring current I_M.

Proportional Band Adjustment No. 7. By shunting the

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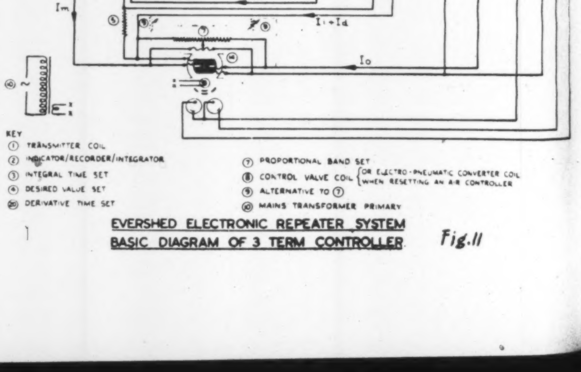

EVERSHED ELECTRONIC REPEATER SYSTEM
BASIC DIAGRAM OF 3 TERM CONTROLLER

Fig. 11

1950 National Exposition *of* Power *and* Mechanical Engineering

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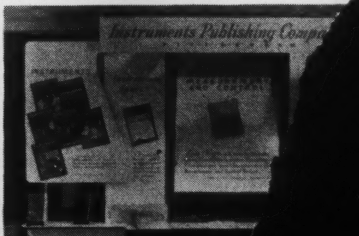
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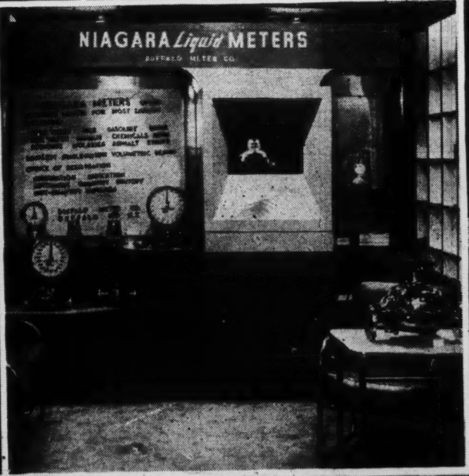
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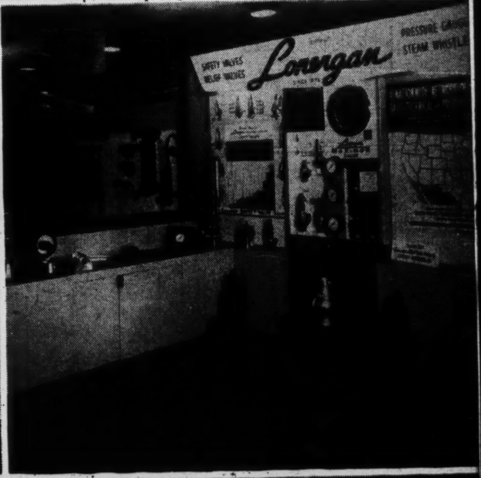
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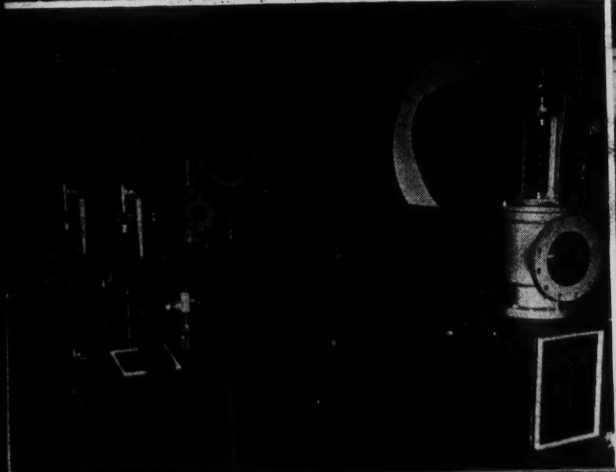

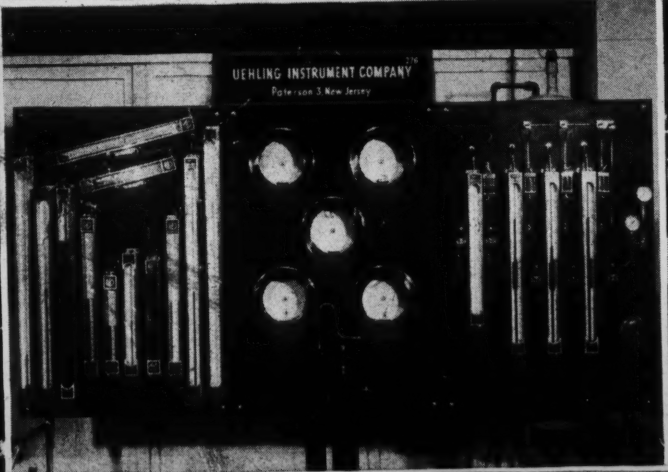
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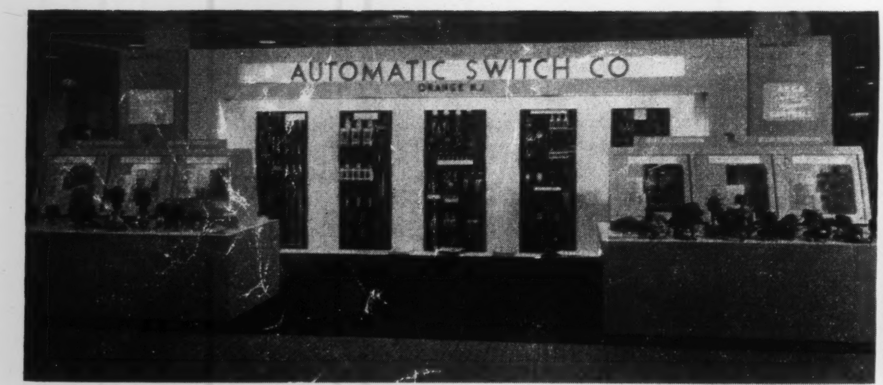
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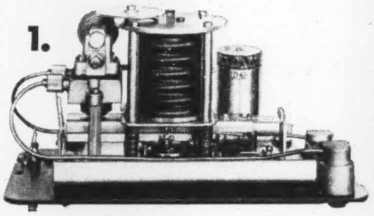

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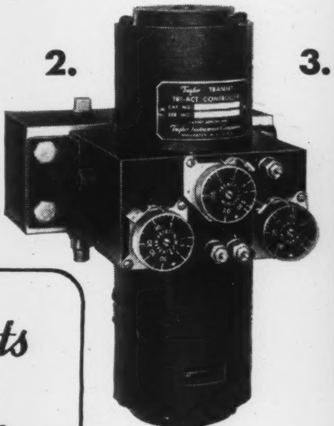

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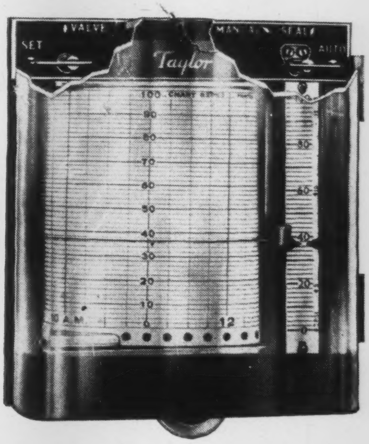

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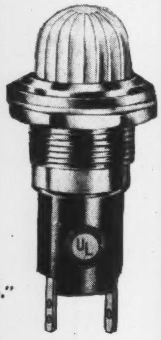

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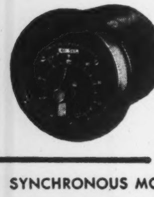

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Continued from page 44

two coils of unit 14 carrying the measuring current and output current to the relay, the sensitivity of valve response may be varied over a wide range. Thus, if the measuring coil is shunted more than the output coil, sensitivity is reduced, giving a wide proportional band. If the output coil is shunted more than the measuring coil, the sensitivity is increased, giving a narrow proportional band. The shunting resistance No. 7 has a variable tapping point which may be adjusted to give proportional band width from 2 to 600 percent.

Desired Value or Set Point. Before describing the method by which integral or automatic reset is achieved, it is necessary to study the means whereby the desired value or set point is established. As the measured condition is represented by a certain current value, it is simple to compare the value with another current representing the desired value or set point. This latter current is derived from a circuit identical with that of the transmitter shown previously in Fig. 1. In this case the plate current in tube No. 22 is maintained at a constant value so that the torque due to the current in a pot coil equals that of a control spring. By shunting the pot coil with variable resistor No. 4, the plate current may be controlled to a predetermined value. It will be seen that it is the current which determines the desired value and passes through one coil of a double-coil movement of integral unit No. 16.

Integral Unit No. 16. This unit detects any deviation from the desired value or set point and produces a current proportional to the integral with respect to time of the deviation. A double-coil movement having permanent magnets and carrying a shutter controls the amount of light to two phototubes of a photoelectric bridge. One coil of the movement receives the measuring current and the other the desired value current and when these currents are equal the shutter is in a central position and the cells are equally illuminated. Any change in the measuring current causes the movement to deflect and the light falling on one cell is increased and the other decreased. The resultant out-of-balance voltage of the bridge is applied to capacitor No. 17 which is charged at a rate proportional to deviation from the desired value. The capacitor is connected between grid and cathode of tube No. 18, the plate current being fed to the measuring coil of proportional unit No. 14. This integral or automatic reset current is superimposed on the measuring current, thereby again varying the output current to the electropneumatic relay.

The variation in output current continues until the measuring current is such to balance the integral unit No. 16 and when the measured quantity is at the desired value.

Integral time is adjusted by resistance No. 3 which controls the brightness of the integral unit lamp and therefore the magnitude of the out-of-balance voltage applied to capacitor No. 17. The integral time control is calibrated 2 to 50 minutes.

Derivative Unit. In order to produce a further component dependent upon the rate of change of the measured condition with respect to time, a differentiating network is included. This consists of a resistor No. 5 in the measuring circuit which therefor has a voltage across it proportional to the measured condition. The ends of the resistor are connected to capacitor No. 19 in series with variable resistor No. 20. With a steady current in resistor No. 5 the capacitor is at a steady state of charge. Any variation of current in resistor No. 5, however, produces a variation of voltage to the capacitor and the charging or discharging current will produce a voltage across resistor No. 20. This voltage is proportional to the rate of change of the measured condition and therefore when applied to the grid of the integral tube No. 18 a derivative component is added to the integral component. The derivative control is calibrated 0 to 20 minutes.

Controller (Constructional Features). A controller case with the cover open is shown in Fig. 12. This particular unit is constructed in aluminum alloy to explosion-proof specifications. When situated in a control room which is considered non-hazardous, the explosion-proof type case

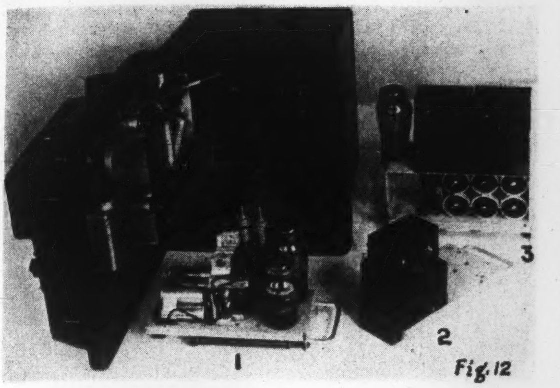

Fig. 12

is not required. The controller components are mounted on trays fitted with multi-pin plugs which engage in sockets at the back of the case.

Tray No. 1 is the measuring unit comprising the desired value component, a single-plate tube for the transmitter current, and a double-plate tube for the desired value current, and the output current to the electropneumatic relay.

Tray No. 2 carries the proportional unit and is used with Tray No. 1. for proportional control.

Tray No. 3 is the three-term unit comprising the integral and proportional units, and the integral tube.

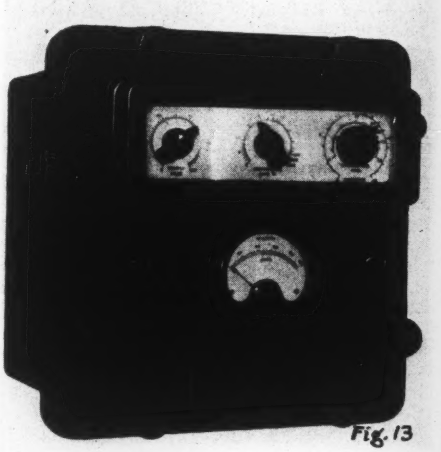

Fig. 13

The controller is shown with the cover closed in Fig. 13. Control adjustments are mounted at the top of the case and consist of pointer knobs moving over calibrated scales.

The left-hand scale is the desired value setting, the middle one proportional band, and the right-hand double scale, integral and derivative settings. The control valve position is indicated by a miniature instrument.

The "Hand Auto" control knob is a two-position switch enabling the operator to disconnect the control valve unit from the automatic controller and operate manually.

The manual control consists of a potential divider operating in a circuit which is independent of the automatic control circuits.

The automatic control units can therefore be removed for servicing when on manual control.

Electropneumatic Relay or Valve Positioner. The output current from the controller as previously mentioned determines the position of the control valve, and Fig. 14 shows diagrammatically the electropneumatic relay or valve positioner. Current from the controller passes through a coil operating in the field of a permanent magnet. The coil is at one end of a pivoted beam the other end having a flapper which covers the nozzle of a low-bleed air relay. One end of a spring link is attached to the beam the other end being connected by a lever to the valve stem, so arranged that when the valve stem moves the spring torque is varied to oppose that of the coil.

When in balance, the spring torque is equal to the torque exerted by the coil which is proportional to the output current. A change in output current will therefore cause the flapper to move relative to the nozzle and vary the air

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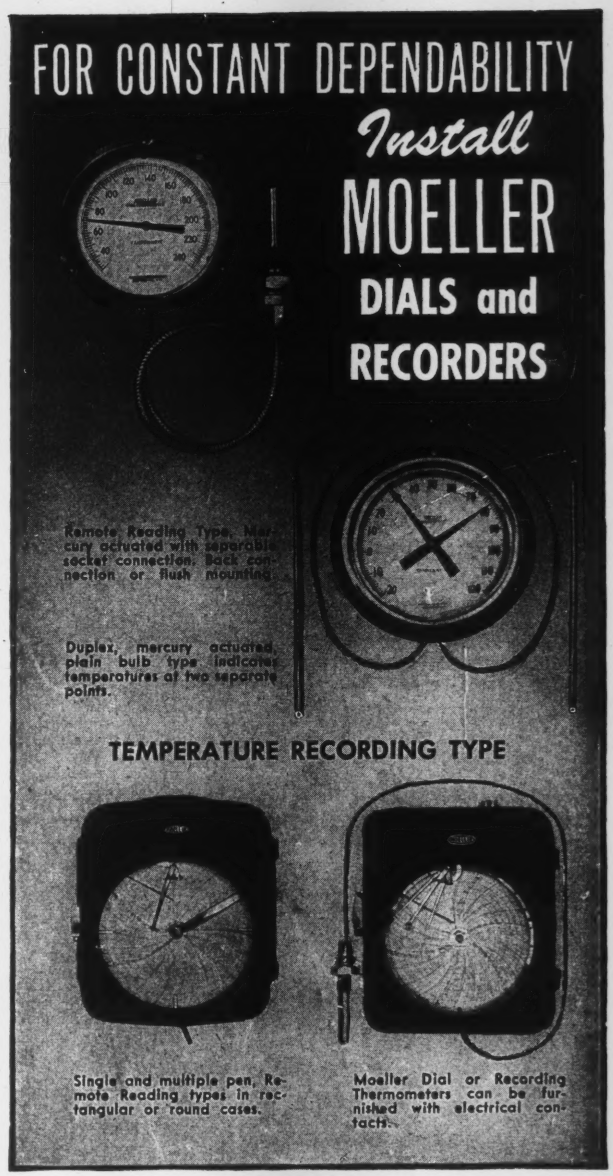

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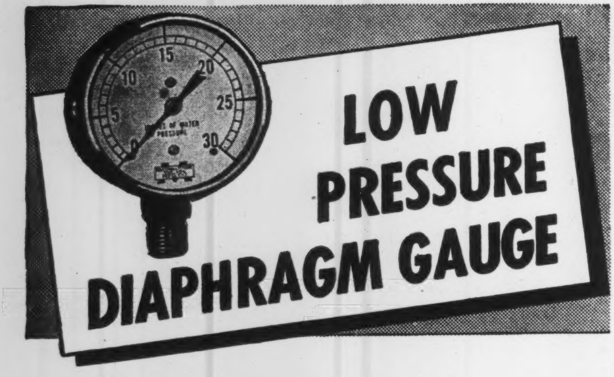

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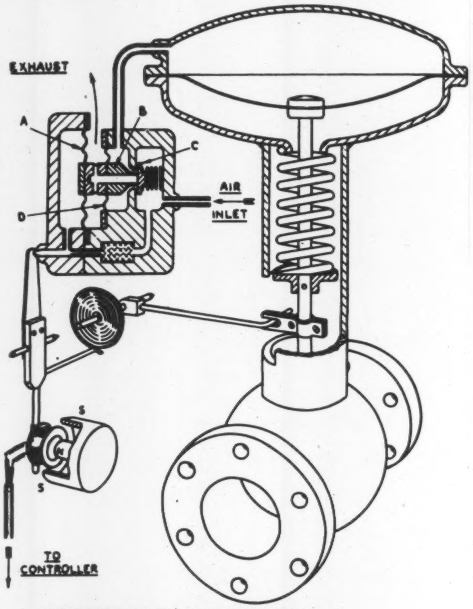
pressure on diaphragm A which will move hollow plunger B. Increase of pressure on A opens spring-loaded valve C and increases air pressure on the control valve diaphragm. Decrease in pressure on A closes valve C and opens hollow plunger B, thus reducing the air pressure on the control valve diaphragm. The control valve continues to move until the force on diaphragm D equals that on diaphragm A. It will be seen that the control valve position is directly proportional to the value of output current from the controller.



REMOTE ELECTRIC CONTROL OF AIR OPERATED VALVE Fig. 14

The electropneumatic relay with cover removed is shown mounted on the head of a diaphragm control valve in Fig. 15. Fig. 16 shows the same unit complete with control valve body.

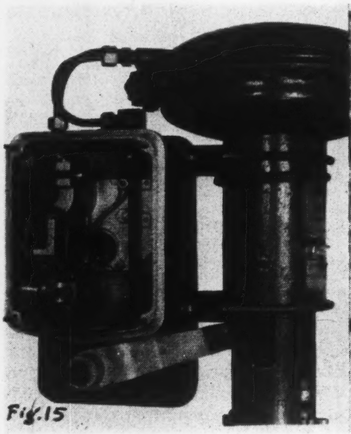


Fig. 15

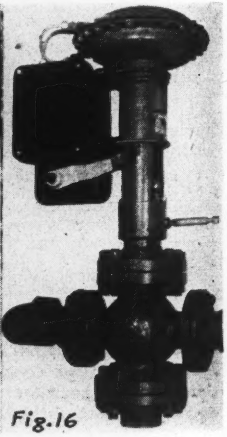


Fig. 16

Centralized Desk Control. Mention has been made of the inherent flexibility of electrical methods and Fig. 17 serves to illustrate this point. The control desk shown is a mock-up made to finalize ideas, prior to going into production. The emphasis in designing this unit has been on an entirely self-contained centralized control desk, complete with indicator, recorder, controllers and, if required, a mimic diagram. The only equipment on the plant would be the transmitters and control valves.

Along the front of the desk small panels are mounted, each of which have the desired value, proportional band, integral and derivative settings, also valve position indicator, and auto to manual controls. Indication is given by minature edgewise indicators, and in this case form part of the mimic flow diagrams. Duplex indicators are used where the measured condition is being automatically controlled the position of one pointer representing the desired value or set point.

Recording. As the measured condition is represented by a current of 0 to 30 ma., it is a simple matter to provide fixed resistances in each circuit and apply the voltage drop across them as an input to multi-point potentiometer recorders. The inputs are connected automatically to two recorders shown in Fig. 17, and the inputs to a third recorder are selected by hand switches on the desk.

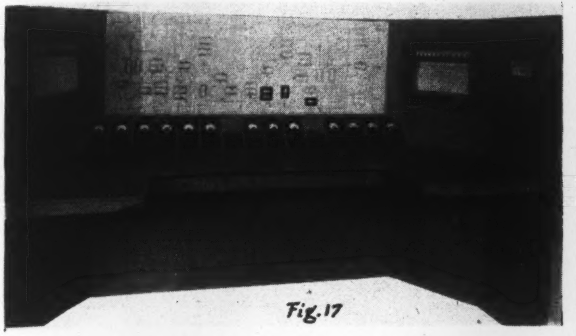


Fig. 17

Mounting of Controller Units. The method of mounting the controller trays is as shown in Fig. 18 which is a photograph of a cubicle for servo amplifier trays and built for another purpose. Similar racks will form an integral part of the desk and will be accessible from the back. Extra compartments will be provided to carry spare trays for service, and enable further controllers to be conveniently added.

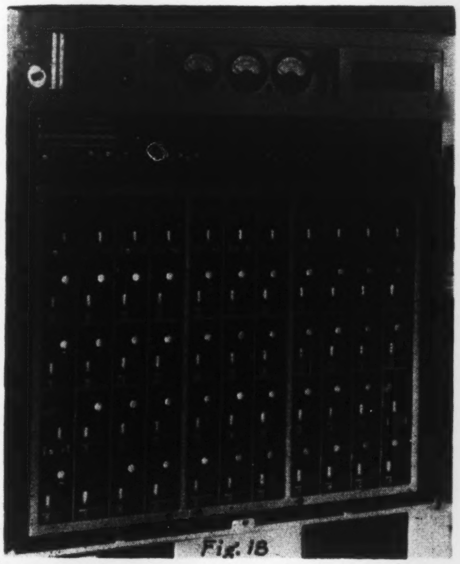


Fig. 18

Precise Indication of Level in Storage Tanks. Before concluding, it might be of interest to describe briefly a method of transmitting accurately the levels of liquids in deep tanks. The system shown in Fig. 19 is one designed to remove the frictional and submergence errors associated with float-operated mechanism. A small displacer is carried by a stainless steel wire passing over a drum. The displacer is supported partly by the liquid which it displaces and partly by a spring. When at rest, a contact carried by the drum spindle lies in a neutral position between two fixed contacts. Any slight change in level will unbalance the system, causing the appropriate contact to be made, thus operating a reversible induction motor. The motor shaft is connected through gearing to a disk carrying the two fixed contacts, and is rotated until the center contact is again in the

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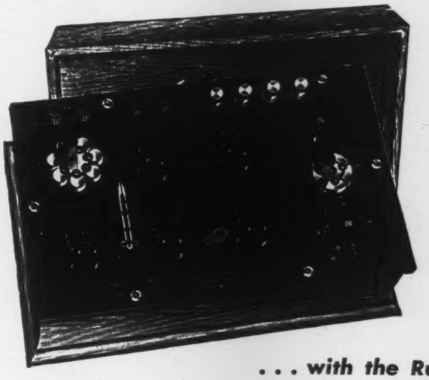

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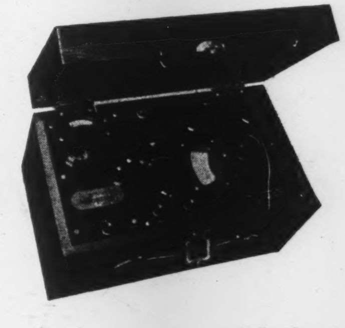

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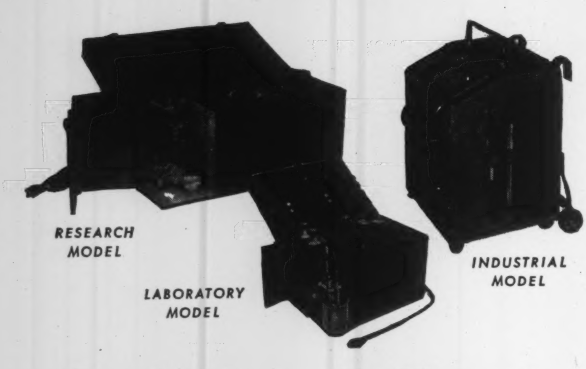
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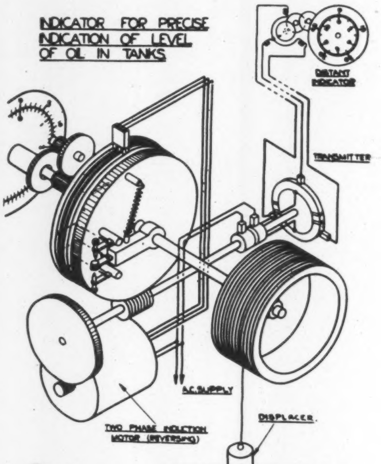
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Fig. 19

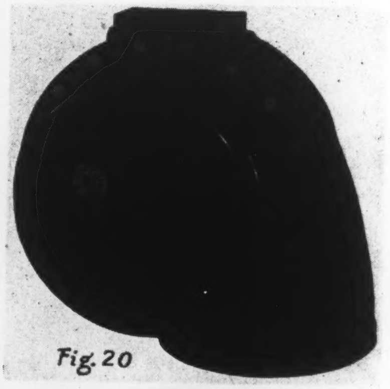

Fig. 20

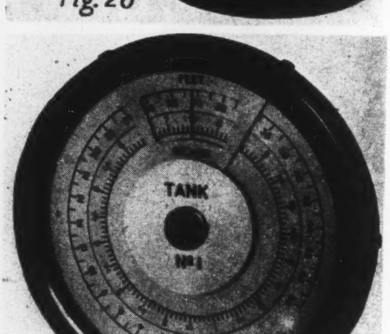
FEET
TANK
No 1

Fig. 21

CONCLUSION

In conclusion the author would like to thank the Agricultural and Mechanical College of Texas and members of the Steering Committee, on behalf of Evershed & Vignoles for the opportunity to contribute to a symposium in a country so renowned for its activities in the field of instrumentation.

POWER PLANT CONTROLS

Continued from page 41

speed are varied by controlling the flow of oil to the coupling. This is done by a regulator-controlling valve in the oil circuit in response to variations in excess pressure applied to a differential in the regulator.

Combustion Control Systems

After the advent of the boiler feed water control system the weary task of always meeting the fuel requirement of the ever-fuel-hungry boilers came to the attention of the "instrument tinkers," who incidentally were now becoming a part of the regular power plant crew.

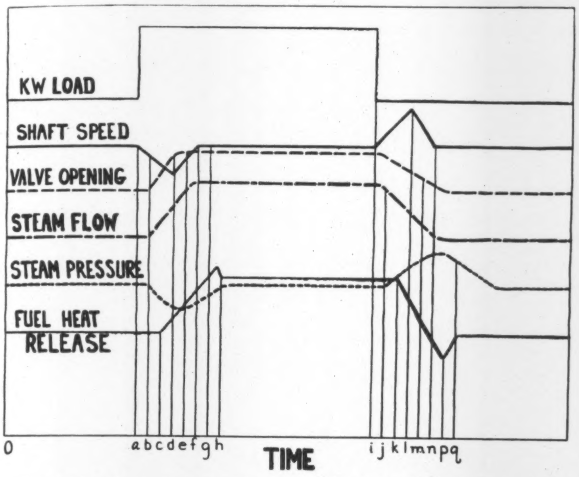

Fig. 12. How load changes on turbine-generator react back to the firing system.

The coming of the instrument technicians was a turning point in power plant operation and efficiency. These energetic young "loafers" were scoffed at and ridiculed by the old hard heads around the power plants. Nevertheless these "yokels" who talked such nonsense as Reynold's Numbers, second and third derivatives, droop correction and dampening action, began to figure out all sorts of ways for automatically performing such laborious tasks as temperature, pressure, combustion, frequency, and load controls. To add insult to injury these young "smart-alecks" proposed to make a KWH for less than one pound of coal whereas it took six pounds. And they did it!

Combustion control is the firing of a boiler automatically irrespective of the type of fuel or load demands. In order to understand just what is expected of combustion control let us look at what happens on load changes in a boiler. (Note Fig. 12)

At 7:30 on a Friday night the flood lights in all the football fields in the community are suddenly turned on. This extra kilowatt load actually slows down the speed of the generator shaft slightly even though the inertia of the generator armature and turbine control valves allows more steam to flow, resulting in a drop in steam pressure at time 7:30 +. When the steam pressure begins to fall, the fireman increases the air supply to the furnace and then the fuel supply in order to liberate more heat. The air supply is increased prior to the fuel supply to take advantage momentarily of furnace stored heat and also to prevent incomplete combustion. This happens at time 7:30 ++.

The increased heat liberated in the furnace checks the boiler steam pressure drop and the loss in the shaft speed, at time 7:30 +++. By time 7:30 ++++ the turbine control valves and steam flow have reached stability for the new load, with the boiler pressure and turbine shaft speed increasing, the latter reaching its normal stability at time 7:30 +++++. At time 7:30 ++++++ the fireman judges from the rapidity of steam pressure rise, that the heat liberation in the furnace is too great and therefore decreases it such that by the time 7:30 +++++++ the

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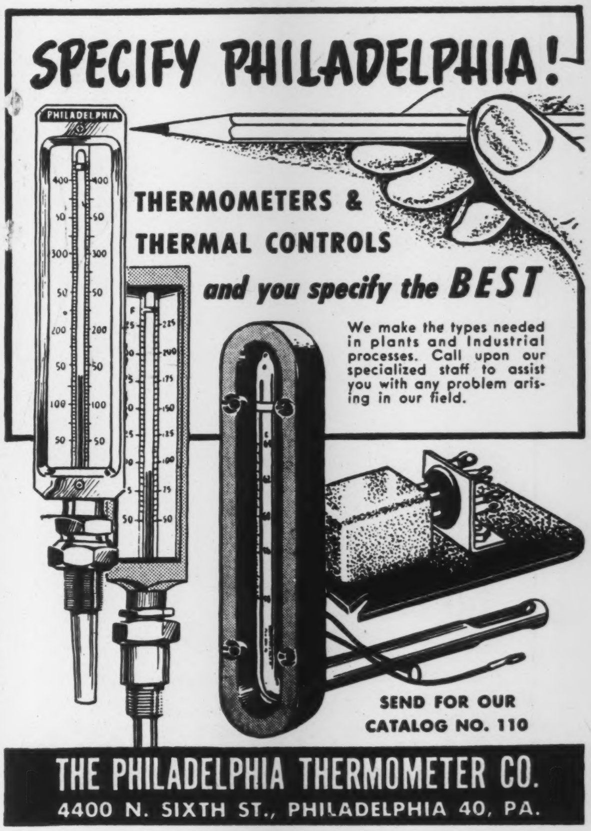
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heat release and steam pressure are constant. The air flow is then adjusted for the new fuel flow.

At 10:00 P.M. the football games are over and consequently the flood lights on the various fields are cut out. At the power station things are happening—lets take a look:

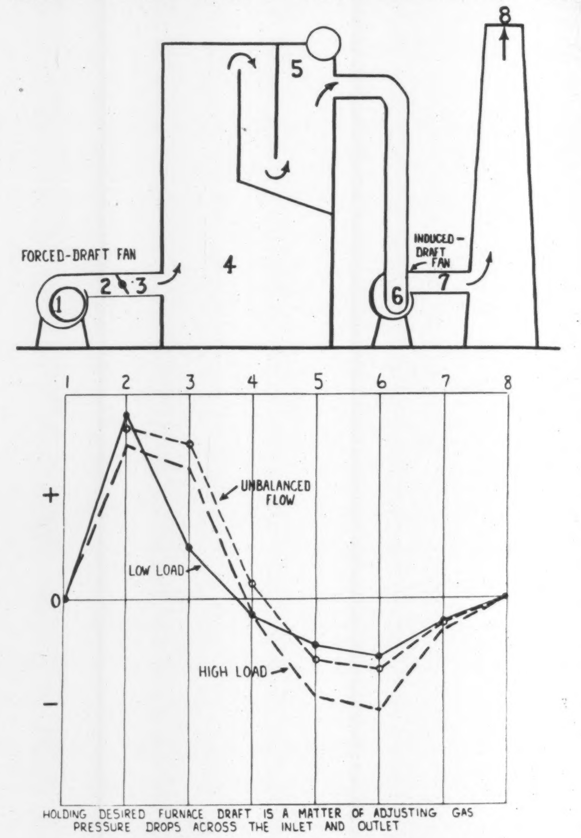
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Fig. 13. How draft conditions change when boiler load varies.

When the football flood lights were turned out, the load on the generator decreased thus decreasing the work required by the turbine. This decrease in work requirement results in the speeding up of the turbine shaft which absorbs some of the steam energy. The governor then actuates the turbine control valves to decrease the steam flow. When this happens the steam pressure begins to rise at 10:00 +.

The fireman observes the rise in steam pressure and adjusts the fuel and air flow to meet the new demand at the time 10:00 ++. At time 10:00 +++ the governor reaches a new balance point where the load is held at just slightly above higher shaft speed, whereupon the governor closes the steam control valves further thus reducing the steam and bringing shaft speed back to normal. At the same time, due to decreased heat liberation in the furnace, the steam pressure has risen to its peak and drops back to normal. At 10:00 ++++++ the firing rate is eased upward to maintain the normal steam pressure.

From the above discussion, it can be more clearly understood just what change takes place when a new steam demand is on a boiler. (Note Fig. 13)

The rate of fuel and air flow must be controlled as well as the boiler furnace pressure which usually operates under a slight negative atmospheric pressure. Moreover a device is required to anticipate the load change and to ascertain the amount of heat release necessary in the boiler furnace. Also, there must be incorporated a device for maintaining certain ratios of fuel to air in order to have good combustion. In short, a combustion control system must automatically coordinate fuel flow and air flow to the steam demand in such a manner as to efficiently operate the boiler on all load ranges.

Essentially there are three types of combustion control:

I. *The "on" and "off" System*

This system is used on small boiler installations. The operation is intermittent in that the fuel and air flow operate "on" and "off" between a given high and low steam pressure setting. The flow of fuel and air are constant during the on period. The primary device, or "master controller" as we call it, operates from the steam pressure header and through relays starts and stops the air flow as well as the fuel flow. This system is usually used on oil or gas fuels, but can be used on stoker-coal fired jobs by adding auxiliary equipment for feeding a small amount of coal and air during off periods to keep the fire banked.

II. *Positioning Control System*

This system operates from a master controller connected to the steam header. The impulse from the steam header is transmitted through a sending relay to a receiving relay element at the power unit by means of any of the conventional transmission systems. The power units "position" the lever, rheostat, valve, etc. (depending on the type of transmission) that regulate fuel feed and air flow.

The master controller may be designed on a drooping steam pressure characteristic, or maintain a constant steam pressure. The fuel and air controls take a definite position when the drooping characteristic is used.

A separate unit maintains a constant furnace pressure by measuring the draft and positioning the power unit which actuates a damper or fan controller.

The positioning method of control assumes that a given position of any controller will always give the same air or fuel flow. Of course this isn't true. For example, the air flow through a boiler setting can be influenced by electric voltage on fan motors, change in resistance through the boiler due to baffle troubles or dirty exterior surfaces, and changes in atmospheric conditions. This system will hold steam pressure constant, but the boiler efficiency may drop off.

III. *Metering Control System*

The metering system of combustion control operates by actually measuring the air and fuel flows against the impulses received from a master controller connected to the steam header.

This characteristic eliminates the positioning effects of power units, and the variations arising in the various methods of transmission, such as voltage, air pressures, and temperatures. Because of this, a fuel-air ratio can be had at all loads to give the maximum combustion efficiency.

The furnace pressure is regulated by a furnace pressure controller actuating a damper or fan (either vane or speed controlled) electrically. The electrical impulses are received from a draft-measuring gadget which energizes the forced draft power unit electrically through the interrupter by means of small electrical contacts when the furnace pressure changes from its normal condition.

There are many good combustion controllers manufactured today. These combustion controllers, while operating on a similar characteristic, vary a great deal in the details of actually controlling the air and fuel flows and furnace pressures. The systems for transportation of the impulses received from the master controller may be pneumatic, hydraulic, electric or a combination of all three. The type of transmission should be duly studied before a certain combustion controller is purchased. For instance, in outdoor boiler installations there is always danger in the winter time of moisture in the air freezing and the hydraulic fluid becoming too viscous. If either of these two transmission systems are being considered, care should be exercised in eliminating the trouble from the two above sources.

STEAM TEMPERATURE CONTROL

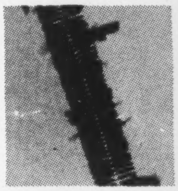
The boiler manufacturers have tried for years to so proportion their superheater surface and arrangement of types of superheaters, such as a combination of convection and radiant heaters, to produce a constant temperature of steam

Continued on page 82

VECO **GAS ANALYZER CELL**

Sealed in Glass For:
- **CONSTANT ACCURACY**
- **LONGER LIFE**
- **TROUBLE-FREE SERVICE**

In a VECO cell all sensitive elements are sealed in glass—protected from clogging residues—safe with explosive gases, unaffected by corrosive gases. VECO gives researchers a higher efficiency with its dependable trouble-free service and constant calibration. Write for details.



END THIS!

This enlarged photo shows carbon and oil impurities clogged in old-style unprotected filament after chemical or exhaust gas analysis. Result is changed resistance, inaccurate readings, after short use.

Victory ***ENGINEERING CORPORATION***
744 Broad St. Newark, New Jersey
VECO CELLS

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COMBUSTION TYPE STARTERS • FINE WIRE PLATING • PURIFIED ZIRCONIUM

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Kemp Dryers save industry thousands of dollars a year—because they protect costly instruments from damage due to moisture in the air or air source. Operation is guaranteed to your specifications, and standard models are available for any instrument air drying operation—whether it's large or small. **Send For Information.** Kemp has a Dynamic Dryer designed for every application. Find out how Kemp can solve your problem. Write today—no obligation.

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DYNAMIC DRYERS
Write for Bulletin D-27 for technical information. C. M. KEMP MFG. COMPANY, 405 E. Oliver Street, Baltimore 2, Maryland.

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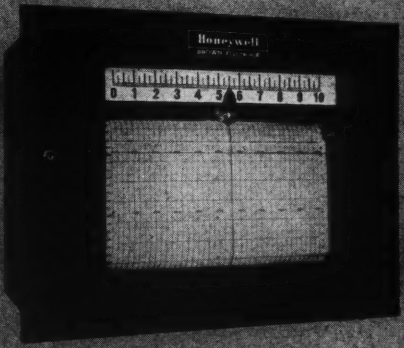
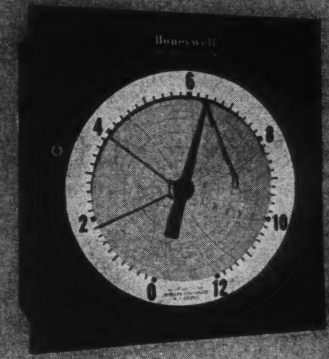
THOUSANDS of users of Brown instruments have found in the products that bear this nameplate a leadership in sound design and construction.

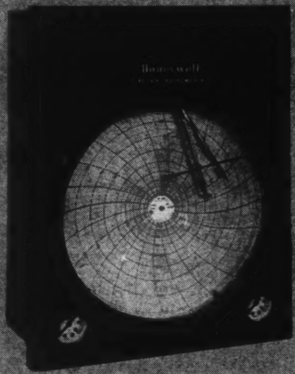
Such qualities have not just happened. Rather, they are the result of constant development and improvement in terms of your ultimate use . . . reflecting practicability as well as suitability for a variety of instrumentation requirements. They are the result of thorough research, common-sense design engineering and practical field testing. Whether you are the owner of the plant, its superintendent, an operating engineer, or an instrument man . . . you will find in Brown instruments the contributions to simplified operation and maintenance, without sacrifice of accuracy, that are most important to you!

Call in your local Honeywell engineer . . . he is as near as your phone. MINNEAPOLIS-HONEYWELL REGULATOR CO., *Industrial Division,* 4482 Wayne Ave., Philadelphia 44, Pa. Offices in more than 80 principal cities of the United States, Canada and throughout the world.

Operation and Maintenance







ElectroniK POTENTIOMETERS

All *ElectroniK* Potentiometers have common operating features which include: (1) the *Continuous Balance* principle that provides instantaneous and continuous responses to emf changes at the detecting element; (2) immunity to effects of vibration; (3) a minimum of moving mechanical parts greatly reducing wear and maintenance requirements; and (4) high operating speeds. These instruments may be used in connection with thermocouples, pH electrodes, Pirani gauges, tachometers, ultraviolet and infrared spectrometers, and other sensing or detecting elements wherein an emf is created. They are available with or without control in strip chart, circular chart, and circular scale types.

The instrument cases are interchangeable for flush and surface mounting. Swing-out chassis, which contain all moving parts, and accessibility of components make for simplified maintenance and operation.

THERMOMETERS, PRESSURE GAUGES, FLOW METERS and LIQUID LEVEL GAUGES

Brown rectangular case instruments are available for recording indicating and/or controlling *Temperature, Pressure, Flow* and *Liquid Level*. All utilize the same case and panel opening and are available for either flush or surface mounting. The ease of range changes, accessibility of and interchange between control units and other components add much to the simplification of operation and maintenance of these instruments.

PYR-O-VANE and *PROTECT-O-VANE* MILLIVOLTMETER CONTROLLERS

The *Pyr-O-Vane* Controller for one, two and three position electric control and the *Protect-O-Vane* excess temperature safety cut-off controller embody many similar features. A universal case interchangeable for flush or wall mounting, independent plug-in measuring unit and control unit, signal lights and ease of control point adjustment are all plus factors toward simplicity of operation and maintenance.

Write for Catalogs

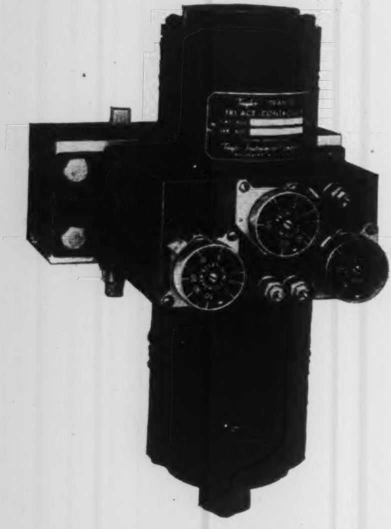
The Month's NEW INSTRUMENTS

In this department we report each month new devices for measurement, inspection, testing, metering and automatic control—in the form of concise technical descriptions.

FOR FURTHER INFORMATION USE THE POSTAGE-FREE ORDER CARD ON PAGE 115

Force-balance Pneumatic Controller

New "Transet Tri-Act" force-balance non-indicating controllers operate in combination with pneumatic transmission systems. Control mechanism contains 2 closed loops in series; first has fixed proportional, and adjustable rate, actions; second has adjustable proportional and adjustable automatic reset actions. Features include high-capacity relay air valve, self-sealing manifold, wide range of control adjustments, nonrotating needle-valve control adjustments, and screw-driver alignment adjustments.—*Taylor Instrument Cos., Rochester* 1, *N. Y.*



Mention No. 101 when filling out card.

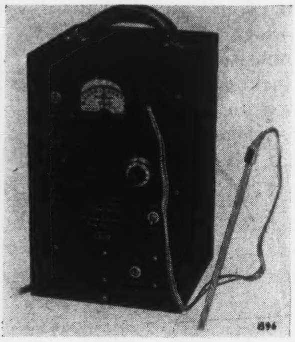
Analytical Mass Spectrometer

New "Model 21-103" mass spectrometer uses new "Isatron" ion source and a stainless steel analyzer. Mass range is extended to 400, and resolving power can be adjusted during operation. New sample-introducing system is machined from stainless steel, and has integral valves. Sample pressure is measured with new electronic micromanometer.—*Consolidated Engineering Corp.,* 620 *N. Lake Ave., Pasadena* 4, *Calif.*

Mention No. 102 when filling out card.

Electronic Resistance Thermometer

New electronic resistance thermometer has a range to 1000 C., with accuracy of 0.1 deg. C. Resistance bulbs are tungsten sealed in Pyrex, or molybdenum sealed in quartz. Instrument operates on 115-v. 60 cps. line.—*Emil Greiner Co.,* 20-26 *N. Moore St., New York* 13, *N. Y.*



Mention No. 103 when filling out card.

Four-pole Remote Position Transmitter

New "Microsyn" consists of a moving element in a four-pole field; it can produce a voltage proportional to rotor position over a range of 20 deg.; or a torque linear with square of a signal current; or a torque proportional to product of square of a current and angular displacement. Magnetic structure is made from specially processed Hipernik.—*Westinghouse Electric Corp.,* 306 *Fourth Ave., Pittsburgh* 30, *Penna.*

Mention No. 104 when filling out card.

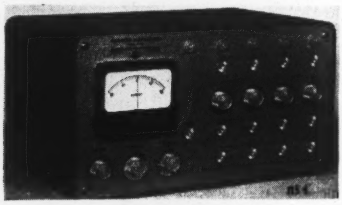
Electrical Hygrometer

New hygrometer element combined with maker's "Electronik" instruments measures relative humidity between 20 and 93 percent, with a minimum span of 20 percent R.H., and temperature compensation from 50 to 120 F. Element consists of interlocked gold leaf combs pressed into a clear plastic base, coated with a salt solution. Conductivity between gold electrodes varies with R.H. of surrounding atmosphere; 63 percent of total change is registered in 10 sec. Over-all accuracy is 1 percent. —*Brown Industrial Div., Minneapolis-Honeywell Regulator Co.,* 4482 *Wayne Ave., Philadelphia* 44, *Penna.*

Mention No. 105 when filling out card.

Carrier Amplifier for Recorders

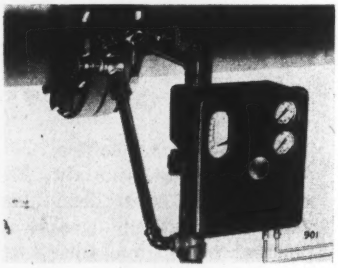
New "Type 1-118, System E" carrier amplifier includes a 3 kc. oscillator, four amplifiers, regulated power supply, and controls. Oscillator output can operate four 120 ohm transducers; attenuator and sensitivity controls for amplifiers provide full-scale output for inputs from 1.875 to 60 mv. Amplifiers have controls for balancing out resistive and reactive signals from transducers and cables. An internal calibrating circuit is provided. Over-all dimensions 9 x 17 x 12 in.; unit operates on 105-125 v., 50, 60, or 400 cps.—*Consolidated Engineering Corp.,* 620 *N. Lake Ave., Pasadena* 4, *Calif.*



Mention No. 106 when filling out card.

Pneumatic Flow Transmitter

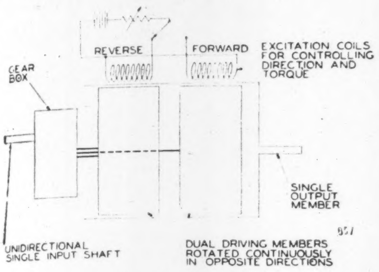
New "V/A Cell" pneumatic transmitter measures flow-rate by by-passing part of main-line flow through a variable-area type instrument. All wetted parts are made of type 316 stainless steel; range tubes from 50 to 1400 in. water are available. Unit uses maker's magnetic coupling to determine float position.—*Fischer and Porter Co., Hatboro, Pa.*



Mention No. 107 when filling out card.

Magnetic Transmission

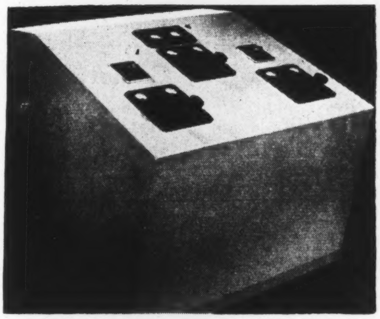
New "Magneclutch" is either a reversible or two-speed magnetic clutch; two input members may be driven by same or different power sources. Input members are driven in opposite directions for reversing action; are driven in same direction at different speeds for two-speed action. Drive is controlled by energizing one of two excitation coils. Excitation power is low, and driven member has low inertia.—*Vickers Electric Div., Vickers, Inc., 1815 Locust St., St. Louis 3, Mo.*


REVERSE
FORWARD
EXCITATION COILS FOR CONTROLLING DIRECTION AND TORQUE
GEAR BOX
SINGLE OUTPUT MEMBER
UNIDIRECTIONAL SINGLE INPUT SHAFT
DUAL DRIVING MEMBERS ROTATED CONTINUOUSLY IN OPPOSITE DIRECTIONS

Mention No. 108 when filling out card.

Electronic Master Control System

New "Telemaster" control system uses electronic amplifiers between master position transmitter and servo follower. Error signal in a-c. Wheatstone bridge circuit may be generated by regulator, or manual loading panel. Final control element position is indicated by voltmeter on control panel; system operates on 40 v. 60 cps. Maker states system operates on null-balance principle, with constant checkback between input and output.—*Republic Flow Meters Co., 2240 Diversey Parkway, Chicago 47, Ill.*



Mention No. 109 when filling out card.

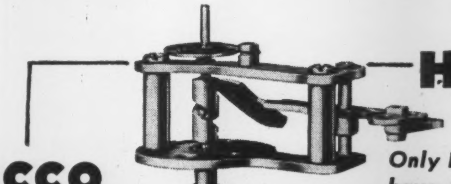
Induction-heated Carbon-determination Apparatus

New induction-heated carbon-determination apparatus employs a quartz sample holder and a coil which heats sample with RF energy. Ignition takes place within 2 min.; assembly also includes a platinum wire catalyst for converting any carbon monoxide to dioxide before passing through carbon dioxide absorbent. Instrument handles alloys with carbon contents ranging from 0.072 to 5.1 percent; accuracy is

"Vive la Difference!"
120
150
180
90
210
60
240
30
270
0
300

● At one time the French Chamber of Deputies was debating women's suffrage. When one liberal soul pointed out that there was very little difference, after all, between the sexes, a fellow deputy leapt to his feet and shouted with gusto, *"Vive la difference!"*

Two pressure gages may seem alike. But the difference between a HELICOID and any ordinary gage is unique. So much so that otherwise complacent engineers, who usually keep their feet on the ground, have been known to jump with ecstasy and exclaim, *"Vive la difference!"*



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INSTANTLY
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Soldering

Controlled dual heat—on in 5 seconds, off when you release trigger—lets you adjust tip temperature for light and heavy instrument soldering. Precision balance, longer reach and tip construction ideal for delicate jobs. Rating up to 250 watts speeds heavy work. Time-and-power savings pay for your Weller Gun in a few months.

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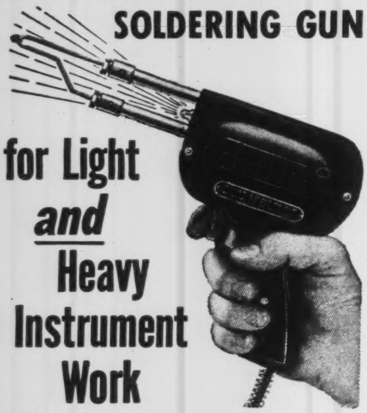

for Light
and
Heavy
Instrument
Work

- TRIGGER-SWITCH CONTROL—Ideal for intermittent work. No need to unplug gun between jobs.
- 5-SECOND HEATING—No waiting, no wasted current.
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See the 250-watt Weller Soldering Gun at your distributor, or write for bulletin direct.

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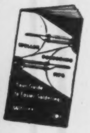


WELLER
ELECTRIC CORP.
800 Packer Street, Easton, Pa.

0.005 percent. Apparatus operates on 230 v. 50-60 cps.—*Fisher Scientific Co., 717 Forbes St., Pittsburgh 19, Penna.*

Mention No. 110 when filling out card.

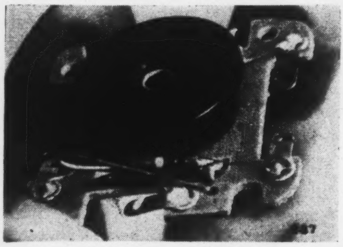
Electronic Proportioning Input Controller

New "Series 4700" input controllers operate with electrically-heated equipment. Instrument automatically adjusts percent on-time of heating elements proportional to unbalance in Wheatstone bridge circuit formed between controller and pyrometer slidewires. Load relays up to 30 amp. 115 v. or 20 amp. at 230 v. non-inductive load are available.—*Automatic Temperature Control Co., Inc., 5200 Pulaski Ave., Philadelphia 44, Pa.*

Mention No. 111 when filling out card.

Static Magnetic Memory

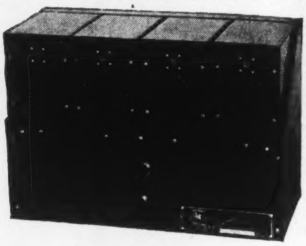
New "Static Magnetic Memory" is based upon a ferrogmagnetic alloy having a fairly rectangular hysteresis loop of low coercive force; it operates essentially as a magnetic trigger pair which require no vacuum tubes to maintain position. Device provides permanent information storage comparable to magnetic drum storage but independent of mechanical movement, a variable information handling rate ranging from zero to 30,000 cps. and pulse information storage without power.—*Alden Products Co., 117 N. Main St., Brockton 64, Mass.*



Mention No. 112 when filling out card.

Predetermined Counter

New Predetermined counter operates when external normally-open contacts are closed; maximum counting rate of 1000 per min. may be extended with a decade scaler. When preset count is reached, instrument closes an electrical circuit and resets to zero for next operation.—*Streeter-Amet Co., 4101 N. Ravenswood Ave., Chicago 13, Ill.*



Mention No. 113 when filling out card.

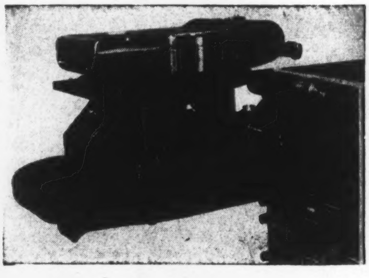
Multi-channel Tape Recorder Drive

New "Type MR-12" 12-channel tape recorder drive mechanism features constant linear tape speed. Unit is designed for seismic analysis; can be used for audio recording. Over-all dimensions 19 x 19 x 10 in., weight 52 lbs.—*Cook Research Lab. Div., Cook Electric Co., 1457 Diversey Pkwy., Chicago 14, Ill.*

Mention No. 114 when filling out card.

Finished-print Recording Camera

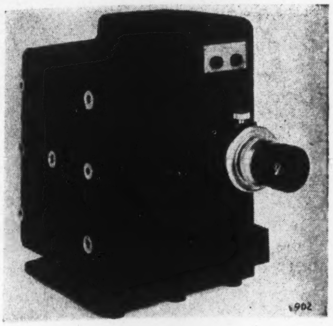
New camera for 5-in. c-r oscilloscope provides finished prints in 1 min., using Polaroid-Land process. Several traces can be recorded on a single print; information can be photographed on prints using an illuminated data card. Coated lens aperture is f/2.8; shutter speeds are adjustable to 0.01 sec.; print size is 2.25 x 3.25 in.—*Instrument Div., Allen B. Dumont Laboratories, Inc., Clifton, N. J.*



Mention No. 115 when filling out card.

Synchronous Motion Picture Camera

New "Model IV" 35 mm. synchronous motion picture cameras are used in parallel-wired gangs, with shutter accuracy of 1 millisecond among all cameras in a gang. Cameras feature coding and timing marker lamps, change gears for frame speeds, con-

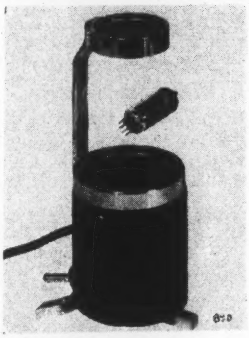


stant temperature film chamber, frame counter, and markers for locating optical center of frames. Cameras at remote locations can be synchronized by a single-channel radio link.—*Flight Research Engineering Corp., P. O. Box 1-F, Richmond 1, Va.*

Mention No. 116 when filling out card.

High-intensity Color Polariscope

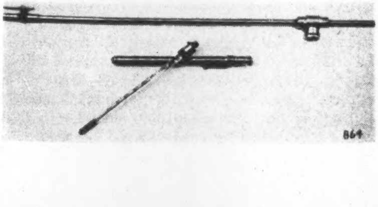
New "Model B" color polariscope shows relative magnitude and location of strains in glass and plastic. Top filter is 1.75 in. diam., bottom filter is 2.5 in. diam. Clearance between filter frames is 3.5 in.; unit may be used vertically or horizontally with immersion cells. High-intensity light source operates on 115 v., a.c. or d.c.; lamp socket is mounted in rubber.—*West Shore Laboratories, Box 117, Marblehead, Mass.*

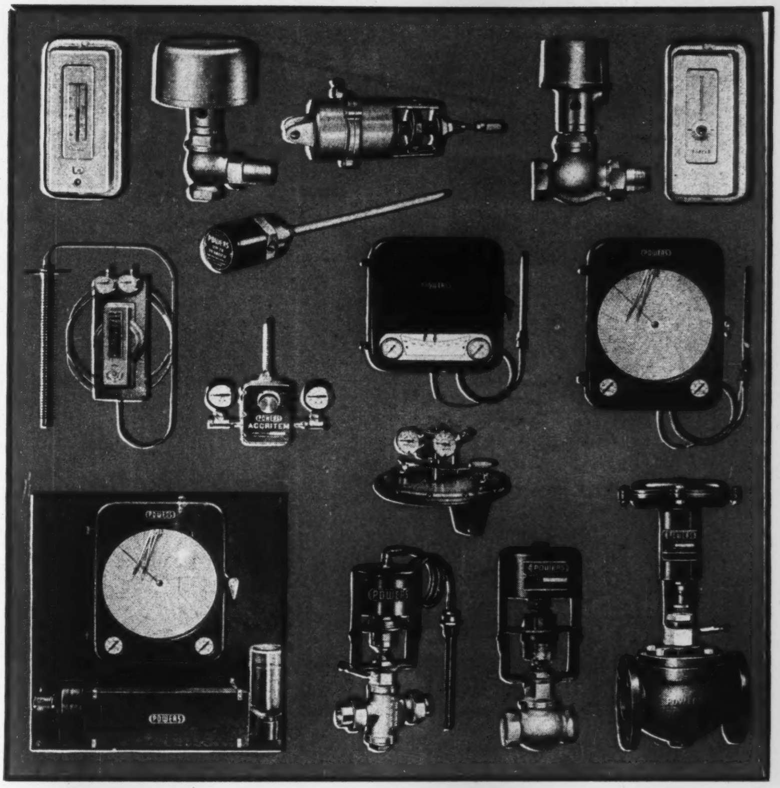


Mention No. 117 when filling out card.

Spot Cooling Device

New "Hilsch Vortex Tube" produces an air flow with sub-zero temperature. In operation, compressed air enters tube through perpendicular base of tee connection, passing into a tangential entry orifice. In resulting vortex, energy distribution is such that with proper adjustment of throttling valve on long arm, heated fraction exits there. Cooled fraction, selected from central mass of vortex by means of a restricting diaphragm in other arm, emerges at this point. Maximum temperature difference





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Prevent OVER-heating, save fuel, increase comfort and efficiency of people in heated rooms with a Powers pneumatic system of temperature control. A sound, highly profitable investment for—Offices, Factories, Process Rooms, Laboratories.

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NEW HIGHS IN RESOLUTION

THE HATHAWAY SC-16A SIX ELEMENT
RECORDING CATHODE-RAY
OSCILLOGRAPH

NEW HIGHS IN RESOLUTION are obtained by this new oscillograph because of its unusually HIGH FREQUENCY RESPONSE and HIGH CHART SPEED... designed for recording fast transients and continuous phenomena.

FREQUENCY RESPONSE 0 to 200,000 cycles per second
RECORDS up to 1000 ft. long at speeds up to 600 inches per second
RECORDS up to 10 ft. long as speeds up to 6000 inches per second
WRITING SPEED above 100,000 inches per second

Note these additional unusual features.

- SIX ELEMENTS with convenient interchangeable lens stages for 1, 2, 3, or 6 traces on full width of chart.
- INTERCHANGEABLE RECORD MAGAZINES for CONTINUOUS RECORDING on strip chart, either 6 inches or 35mm in width up to 1000 feet in length, DRUM RECORDING for short, high-speed records, and STATIONARY CHART for very short transients.
- PRECISION TIMING EQUIPMENT, tuning fork controlled, for 1-millisecond or 10-millisecond time lines.
- Crystal-controlled Z-AXIS MODULATION for 1/10 millisecond time marks.
- QUICK-CHANGE TRANSMISSION for instantaneous selection of 16 record speeds over a range of 120 to 1.
- AUTOMATIC INTENSITY CONTROL.
- CONTINUOUS SWEEP OSCILLATOR which permits viewing as well as recording.
- Single-pulse LINEAR OSCILLATOR for recording transients on stationary film. The record can initiate the transient to be recorded, or the transient can initiate the record.

Each recording element is a complete unit, fully housed, which can be instantly inserted or removed. Recording element contains high-intensity cathode-ray tube, and both AC and DC amplifiers. Control panel is located on outside end.

FOR FURTHER INFORMATION, WRITE FOR BULLETIN 2 G-I-H

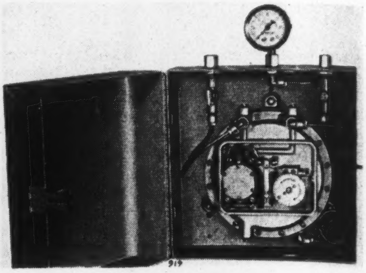
Hathaway
INSTRUMENT COMPANY
1315 SO. CLARKSON STREET • DENVER 10, COLORADO

is attained with flow regulated to produce a division of approximately 70 percent hot and 30 percent cold. Parts are chrome-plated brass assembled in tight joints.—*Thermo Instruments Co. 1111 El Camino Real, Belmont, Calif.*

Mention No. 118 when filling out card.

Air Velocity Controller

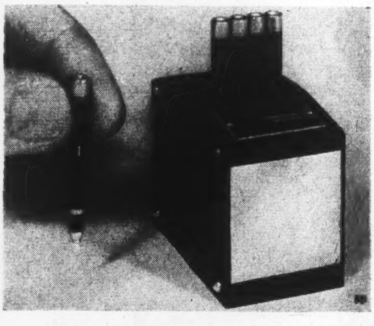
New controller measures air velocity by pressure difference between two points; flexible diaphragm element responds to changes of 0.0001 in. water. Proportional pneumatic mechanism has a control range from 50 to 250 fpm.—*Johnson Service Co., Milwaukee 2, Wis.*



Mention No. 119 when filling out card.

Super-sensitive Galvanometer

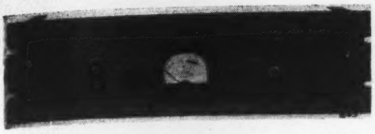
New "Model 106-SS" galvanometer has a normal balance of 0.003 in. per g. at 12 in. focal distance, but can be balanced to less than 0.001 in. deflection per g. Outside diameter of element tube is 0.187 in., element length is 2.062 in. Units are available with nominal undamped natural frequencies of 100, 150, and 200 cps.—*Midwestern Geophysical Laboratory, Tulsa, Okla.*



Mention No. 120 when filling out card.

Sound Spectrum Analyzer

New "Type 1000B" sound spectrum analyzer combines maker's condenser microphone complement, octave band filter, and VTVM. Range of sound pressure level is 30 to 150 db; reading is given by sum of scale switch plus indicator. Filter set provides high- and low-pass filters in tandem with complete isolation. Cut-off frequencies range from 75 to 4800 cps. A monitor jack permits use of headphones. With steady sound level, unit is accurate to 0.2 db. Over-all dimensions 19 x 17.5 x 11 in.,

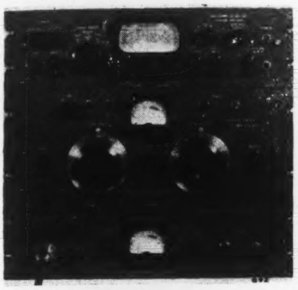


weight 50 lbs.; operates from 115-v. 50 to 400-cps. line.—*Western Electro-Acoustic Laboratory, 204 S. Beverly Dr., Beverly Hills, Calif.*

Mention No. 121 when filling out card.

Thermal Noise Source

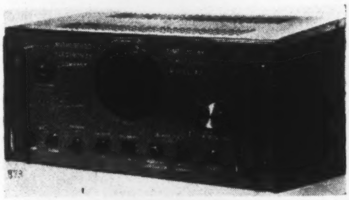
New "Type 300A" thermal noise source has an output of 1 v. for a frequency band up to 20 kc., with 20 ohms output impedance; minimum load is 500 ohms. Resistive noise source furnishes constant energy per cycle, rising 3 db per octave; internal noise is 10 db below thermal spectrum. Over-all dimensions 19 x 5.25 x 7.75 in., weight 14 lbs.—*Western Electro-Acoustic Laboratory, 204 S. Beverly Dr., Beverly Hills, Calif.*



Mention No. 122 when filling out card.

Time Delay Generator

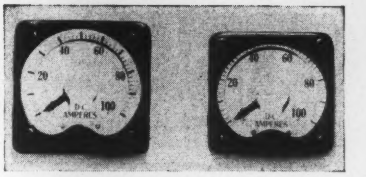
New "Model A2" time delay generator produces variable delays ranging from 0.4 to 100,000 microseconds. Five ranges provide full scale reading of 10 microseconds delay on lowest range, with progression by decade steps. Blocking oscillator and single shot multivibrator output waveforms are provided; oscillator pulse is 0.5 microsecond wide with a rise time of 0.1 microsecond. Multivibrator output pulse is presented through a low impedance cathode follower; its width is a function of delay range in use. Over-all dimensions 9 x 19, 5 x 15 in.—*Rutherford Electronics Co., 3724½ S. Robertson Blvd., Culver City, Calif.*



Mention No. 123 when filling out card.

Full-view Switchboard Instruments

New "Full-View Type K-24" circular scale switchboard instruments provide maximum readability from steepest angles and cause no objectionable shadows on scale, maker states. Cover is approximately 0.375 in. wider and higher than previous design, but drilling plan for two types is identical.—*Westinghouse Electric Corp., Box 2099, Pittsburgh 30, Pa.*



Mention No. 124 when filling out card.

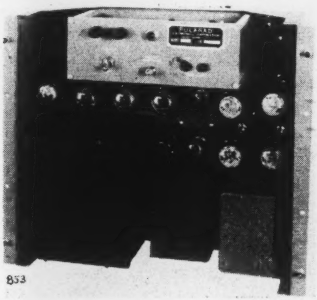
D-C. Power Supply and Bridge Control

New "Model 128" provides 0 to 100 v. d.c. at 100 ma., with less than 1 mv. a-c. ripple. Bridge balancing circuit uses a 10-turn voltage divider; has a polarity reversing switch, and calibrating shunt. Unit has an oscilloscope output jack, and a 120-cps. chopper between signal and ground. External batteries can be used for bridge power through front-panel terminals.—*Industrial Electronics, Inc., 8060 Wheeler St., Detroit 10, Mich.*

Mention No. 125 when filling out card.

Regulated Power Supply

New "Model PT-112" power supply is adjustable from 250 to 300 v.; delivers 800 ma. Regulation is 0.02 percent, output impedance is 1.5 ohms.—*Polarad Electronics Corp., 100 Metropolitan Ave., Brooklyn 11, N. Y.*



Mention No. 126 when filling out card.

Two-circuit Power Supply

New "Model 500-DVS" power supply operates from 120-v. 60-cps. line. No. 1 circuit furnishes 0 to 750 v. a.c. at 200 ma. maximum; 0 to 10 amp. a.c. up

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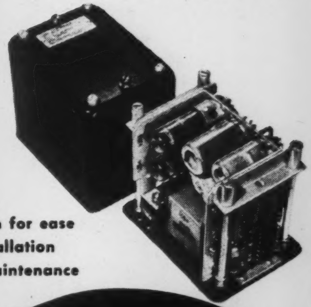

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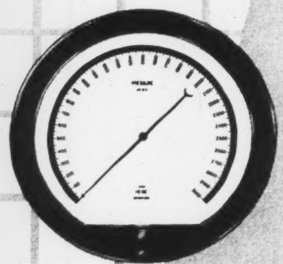

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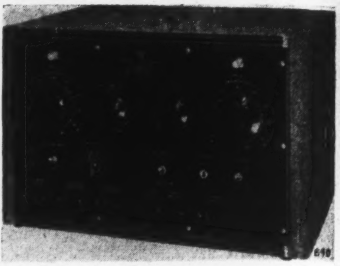
Newtown, Connecticut

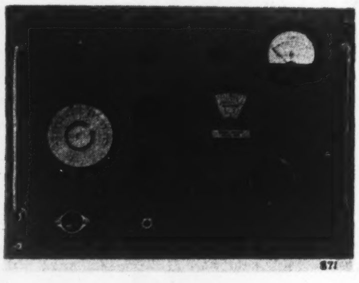


to 8 v.; 0 to 750 v. d.c. at 175 ma. maximum. No. 2 circuit furnishes 0 to 120 v. a.c. up to 3 amp.; 0 to 10 amp. a.c. up to 10 v.; 0 to 150 amp. a.c. up to 2 v.; and 0 to 10 amp. d.c. up to 3 v. Circuits are separately controlled and electrically isolated. Over-all dimensions 21.5 x 15.75 x 15 in.—*Arthur E. Booth Co.,* 4124 *Beverly Blvd., Los Angeles* 4, *Calif.*

Mention No. 127 when filling out card.

Super-high-frequency Signal Generator

New "Model 618A" signal generator furnishes coverage from 3,800 to 7,600 Mc.; all frequencies are directly read on central tuning dial. Instrument provides a 1 milliwatt signal into a 50-ohm coaxial load at zero dbm; an output attenuator reduces level to less than −100 dbm. Repeller voltage tracks automatically, and no adjustment is required to select correct frequency. Accuracy is 0.5 percent. Unit may be externally frequency-modulated with maximum deviation of 10 Mc.; it may be externally pulse-modulated, with a positive or negative peak voltage of 15 v.; internal square-view modulation is also provided within range of 400 to 1,000 cps.—*Hewlett-Packard Co.,* 395 *Page Mill Road, Palo Alto, Calif.*



Mention No. 128 when filling out card.

Wired Television Transmitter

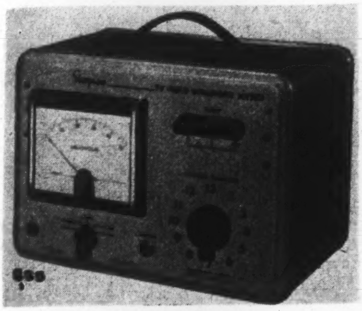
New "Dumitter" takes composite video signal from any standard TV camera chain and feeds to regular antenna terminals of any standard TV

receiver. Both video and aural signals are fed through a single coaxial cable; up to 125 receivers can be driven simultaneously. Due to carrier frequency used, attenuation in feed line is not serious, and no special termination is needed for equalization. Each receiver is tuned to either Channel 2 or 3, and closed-circuit program is received. Antenna lead-in is disconnected from receiver while signal is being received.—*Television Transmitter Div., Allen B. DuMont Laboratories, Inc., Clifton, N. J.*

Mention No. 129 when filling out card.

TV Field Strength Indicator

New "Model 488" field strength indicator incorporates a 12-channel TV tuner; instrument indicates from 0 to 50,000 microvolts in four ranges. Phone jack is included for audible tests. Overall dimensions 8 x 11 x 8.5 in., weight 11.5 lbs.—*Simpson Electric Co., 5216 Kinzie St., Chicago 44, Ill.*



Mention No. 130 when filling out card.

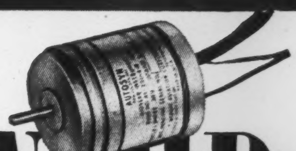
Stroboscopic Frequency Meter

New "Model 6T-4 Stroboconn" frequency meter, accurate to 0.05 percent, is designed for industrial use. Instrument is calibrated in cps.—*Electronics Div., C. G. Conn Ltd., Elkhart, Ind.*

Mention No. 131 when filling out card.

Miniature CRO

New miniature c-r. oscilloscope measures 9 x 6 x 14.5 in., weighs 17 lbs. Sweep frequency range is 3 cps. to 50 kc. Vertical response is flat within 3 db from d.c. to 2 Mc.; horizontal amplifier is flat within 2 db from d.c. to 100 kc. Instrument features blanking and synchronizing amplifiers; deflection sensi-



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	One Control Transformer	Two Control Transformers	Three Control Transformers
INPUT			
Voltage	26-volts, single-phase	26-volts, single-phase	26-volts,single-phase
Frequency	400 cycles per second	400 cycles per second	400 cycles per second
Current	105 milliamperes	130 milliamperes	155 milliamperes
Power	0.90 watts	1.4 watts	1.9 watts
Impedance	85+j240 ohms	80+j180 ohms	77+j149 ohms
OUTPUT			
Voltage max. (rotor output)	18.0 volts	15.5 volts	13.3 volts
Voltage at null	30 millivolts	20 millivolts	20 millivolts
Sensitivity	315 millivolts/degree	270 millivolts/degree	230 millivolts/degree
Voltage phase shift	18.5 degrees	24.5 degrees	28.0 degrees
System accuracy (max. possible spread)	0.5 degrees	0.5 degrees	0.5 degrees

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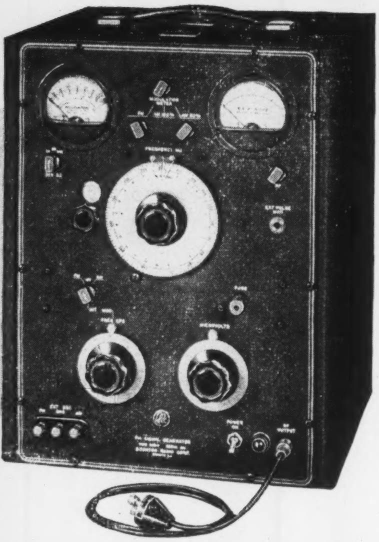

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MODEL 202-D
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RF RANGE: 175-250 megacycles, accurate to ± 0.5%. Main frequency dial also calibrated in 24 equal divisions for use with vernier frequency dial.

FREQUENCY MODULATION (Deviation): FM deviation continuously variable from zero to 240 kc. Modulation meter calibrated in three FM ranges: 0-24 kc., 0-80 kc., and 0-240 kc.

AMPLITUDE MODULATION: Utilizing the internal audio oscillator amplitude modulation may be obtained over the range of 0-50%, with meter calibration points at 30% and 50%. By means of an external audio oscillator the RF carrier may be amplitude modulated to substantially 100%.

RF OUTPUT VOLTAGE: The RF output voltage is continuously variable from 0.1 microvolt to 0.2 volt at the terminals of the output cable; Output impedance at front panel jack is 53 ohms resistive.

DISTORTION: The overall FM distortion at 75 kc deviation is less than 2% and at 240 kc. less than 10%. The AM distortion at 50% is less than 6.5%.

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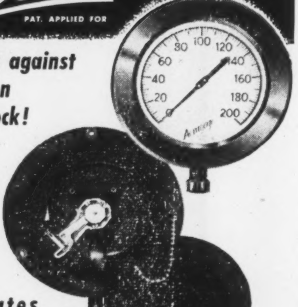

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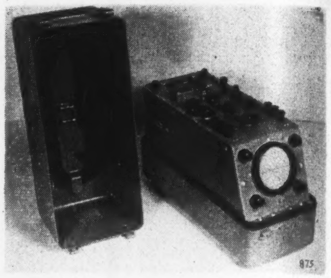
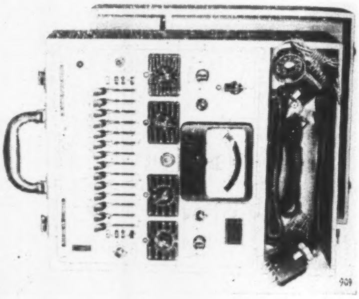


tivity exceeds 0.5 v. per in. when operated from 105-125 v. at 50-1000 cps. —*Hycon Mfg. Co.*, 2961 *E. Colorado St., Pasadena* 8, *Calif.*

Mention No. 132 when filling out card.

C-r. Tube Tester

New "Model CR-30" can test TV picture tubes in the set, or carton. Instrument checks tubes with electron-gun in operation, using beam current test circuit. Features include a voltage-regulated VTVM, 14-lever selector system, and internal calibrating controls. Over-all dimensions 13.75 x 17.25 x 6.75 in.—*Precision Apparatus Co., Inc.*, 92-27 *Horace Harding Blvd., Elmhurst, L. I., N. Y.*



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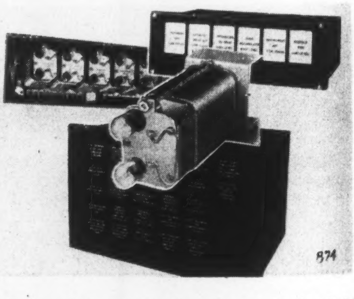
Back-lighted Multiple Unit Signal

New back-lighted multiple unit signal is hermetically sealed, combining signal lights and relay. One-piece unit plugs into a universal chassis, and is held by a thumb nut on a locking stud. Cabinets may be obtained with any number of alarm units; designation plates for each signal are printed or engraved.—*Panalarm Products Co.*, 7218 *N. Clark St., Chicago* 26, *Ill.*



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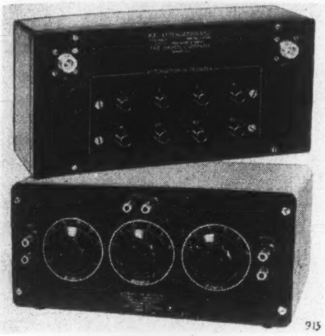
Attenuators

New "Model 650" RF attenuation network has a flat response from d.c. to 225 Mc.; insertion loss is zero over this range. Unit has a total of 100 db in 1 db steps; resistors are calibrated to 2 percent accuracy at d.c. Attenuation is inserted in circuit by push-button switches. New "Model 795" decade attenuator operates from d.c. to 200 kc., can be used up to lower RF range. Units are available with a total of 110 db in 1 db steps, or 111 db in 0.1 db steps. Below 200 kc., total error in attenuation will not exceed 1 percent of value indicated by rotary switches.—*Daven Co.,* 191 *Central Ave., Newark* 4, *N. J.*



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Voltage Take-off Connection

New "No. 400 PT" voltage take-off consists of a thin plate which slips over prongs of Edison plugs, and has tip jacks from which voltage is measured.—*Industrial Devices, Inc., Edgewater, N. J.*

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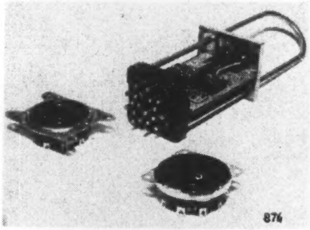
Non-interchangeable Base and Socket

New 20-pin base and socket can be used with cards, brackets, bails, etc. Variations in pin layout orients base and socket. Clips can carry 17 amp., and clip retention force is variable. Bases are available for chassis or rack layout.—*Alden Products Co.,* 117 *N. Main St., Brockton* 64, *Mass.*



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Electrical Network Housing

New "Labcase" housing is 4 in. long by 1.5 in. diameter. Models are available for 3- and 4-terminal networks. Input terminals are banana type with

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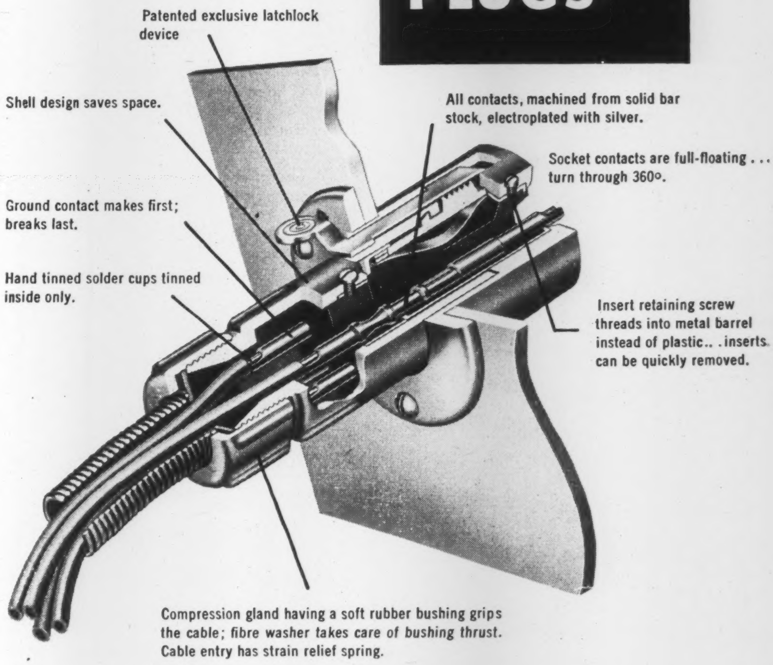
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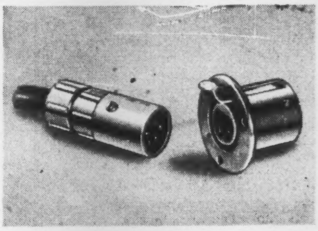

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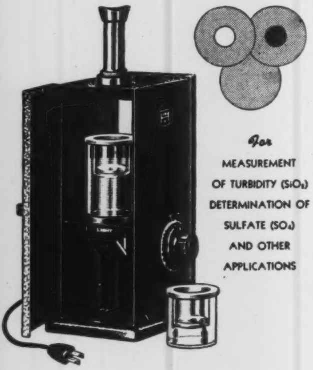

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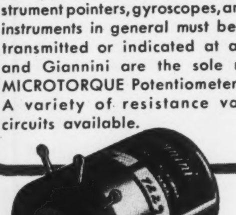

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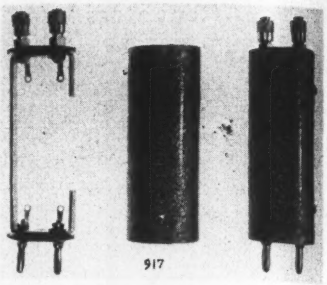
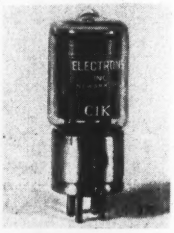


0.75-in. spacing; output binding posts take banana plugs, spade tips, or plain wire ends.—*Berkshire Laboratories, 508 Lexington Rd., Concord, Mass.*

Mention No. 138 when filling out card.

Gas-filled Grid-controlled Rectifier Tube

New "Type EL-C1K" gas-filled grid-controlled rectifier tube has an average anode current 1 amp. d-c.; peak anode current 8 amp.; max. peak inverse voltage 1250; max. peak forward voltage 1000. Average arc drop is 8 v. and filament draws 6.3 amp. at 2.5 v., with a heating time of 25 sec. Grid shielding results in a grid-anode capacitance of 1 uuf with a grid-cathode capacitance of 10 uuf. Critical grid current is less than 5 microamps.—*Electrons, Inc., 127 Sussex Ave., Newark 4, N. J.*



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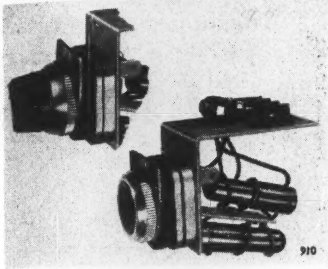
RF Step-up Coils

New RF step-up coils have secondary output of 35 kv. 5 ma. at 70 kc. Used in a special circuit, voltages up to 90 kv. can be obtained. Primary is 4 in. high by 4.25 in. diam.; secondary is 7 in. high, and consists of 10 pie windings 3 in. diam.—*Spellman Television Corp., 3029 Webster Ave., Bronx 67, N. Y.*

Mention No. 140 when filling out card.

Mercury Safety Switch

New mercury safety switch is hermetically-sealed unit mounted on a lever-operated armature, with either push-button or selector knob operator.

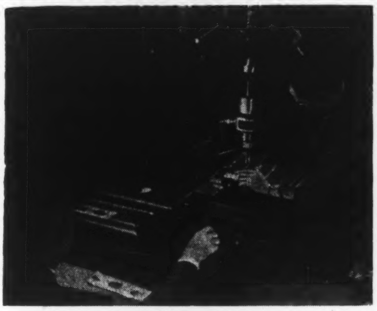


Switch is designed for vertical mounting; is available s-p.s-t. or s-p.d-t. Spring in push-button model returns switch to original position when finger pressure is released.—*Panalarm Products, Inc., 7212 N. Clark St., Chicago 26, Ill.*

Mention No. 141 when filling out card.

Torque-measuring Instrument

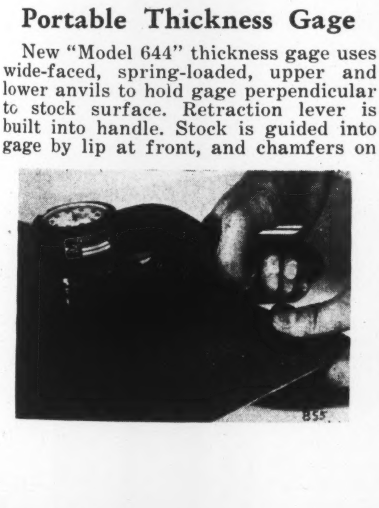
New "SR-4 Torquemeter" is a short shaft to which maker's resistance strain gages are bonded, to form a Wheatstone bridge. Corners of bridge are connected to a recording oscillograph, through brushes and slip rings. Instrument absorbs negligible power from shaft being studied; illustration shows application to power tapping.—*Baldwin Locomotive Works, Eddystone, Pa.*



Mention No. 142 when filling out card.

Portable Thickness Gage

New "Model 644" thickness gage uses wide-faced, spring-loaded, upper and lower anvils to hold gage perpendicular to stock surface. Retraction lever is built into handle. Stock is guided into gage by lip at front, and chamfers on



Timing Ideas

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You can always count on Haydon to provide the right motor for your timing job. Timing Headquarters offers a broad line of efficient, economical timing motors and timers produced by specialists who have no other interest than to provide the best in timing.

LOW COST VERSATILITY—1600 SERIES:
Specifically designed as a standard component for the widest possible range of timing applications with 79 speeds from 300 rpm to 1 revolution per 4 hours.

COMPACTNESS AND SLOW SPEED—4400 SERIES:
Designed for small size and low cost in applications requiring slower speeds from 6 hours to 7 days per revolution.

HEAVY DUTY DEPENDABILITY—3100 SERIES:
For control and instrument applications that require a heavy duty train and speeds from 1 hour to 14 days per revolution.

SUPERIORITY FEATURES
Slow (450 rpm) rotor speed makes for quiet operation and long life. Unusually small. All motors totally enclosed. Separate rotor and reduction gearing lubricating systems permit selection of best methods and lubricants, control circulation, insure against leakage. Operates continuously in any position. Simple to mount, entire face of motor can be supported securely against mounting surface. Standard, interchangeable design in only 2 motor series with speed range from 300 rpm to 1 revolution in 7 days.

1600

4400

3100

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Automatic's relays are not built to a price but to an unexcelled standard of performance. That's why they are the choice of so many "big name" manufacturers.

We engineer and build a wide variety of stock model relays for practically all applications. A staff of competent engineers will design and build relays to fit *your* requirements.

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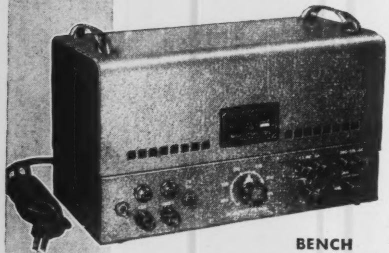

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BENCH MODEL 25

STABLE
DEPENDABLE
MODERATELY PRICED

- INPUT: 105 to 125 VAC. 50-60 cy
- OUTPUT #1: 200 to 325 Volts DC at 100 ma regulated
- OUTPUT #2: 6.3 Volts AC CT at 3A unregulated
- RIPPLE OUTPUT: Less than 10 millivolts rms

WIDTH 14"
DEPTH 6"
HEIGHT 8"
WT: 17 LBS.

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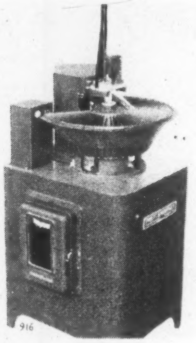
anvils. Indicator can have direct or continuous reading dial.—*Federal Products Corp.*, 1144 *Eddy St.*, *Providence* 1, *R. I.*

Mention No. 143 when filling out card.

Automatic Gaging & Classifying Instrument

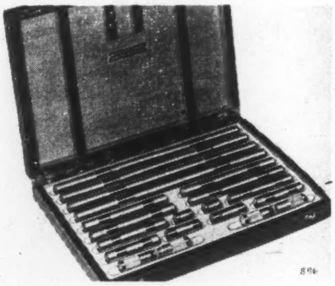
New "Selectronic" gage application separates carbon vanes into 32 classes, in increments of 0.0001 in. Vanes are machine fed under maker's "Electrolimit" gaging head, which operates, through a photoelectric control unit, the chute-positioning mechanism.—*Pratt & Whitney Div., Niles-Bement-Pond Co., West Hartford* 1, *Conn.*



Mention No. 144 when filling out card.

End Measuring Rods

New end measuring rod sets are hardened, seasoned, and lapped to Johansson Gage Block tolerance of "A" quality 0.000004 and "B" quality 0.000008 per in. Set consists of two each 1, 2, 3, 4, 5, and 6 in. rods, four 12 in. rods, and two 4 in. micrometer heads.—*Swedish Gage Co. of America*, 8900 *Alpine Ave.*, *Detroit* 4, *Mich.*



Mention No. 145 when filling out card.

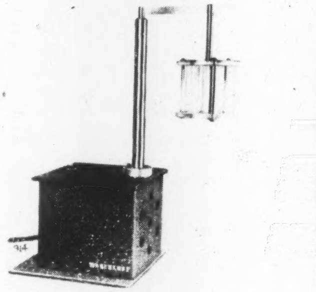
Tin Plating Thickness Gage

New tin plating thickness gage operates by directing high-intensity collimated X-radiation on to plated test sheet. Emergent radiation is measured by a Geiger counter, which operates printed-tape registers. Coatings as thin as 1 millionth in. can be measured.—*North American Phillips Co., Inc.*, 100 *E. 42nd St.*, *New York* 17, *N. Y.*

Mention No. 146 when filling out card.

Tablet Disintegration-rate Tester

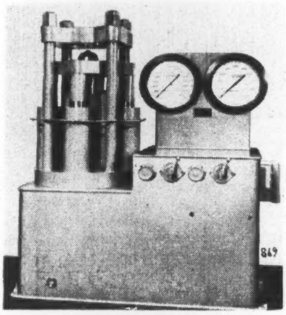
New tablet disintegration-rate tester has a motor-driven basket-rack assembly which moves up and down in a water bath at 30 cycles per min. Six tablets are tested simultaneously; their condition during test can be observed through glass and plastic parts. Unit operates on 110-v. 60-cps. line.—*Panray Corp.*, 340 *Canal St., New York* 13, *N. Y.*



Mention No. 147 when filling out card.

Ductility Testing Machine

New ductility testing machine is motorized, hydraulically operated, with separate control for clamping force up to 100,000 lbs., and penetrating force up to 150,000 lbs. Both 0.875 and 5 in. diam. penetrators are provided in one unit.—*Steel City Testing Machines, Inc.*, 8843 *Livernois, Detroit* 4, *Mich.*



Mention No. 148 when filling out card.

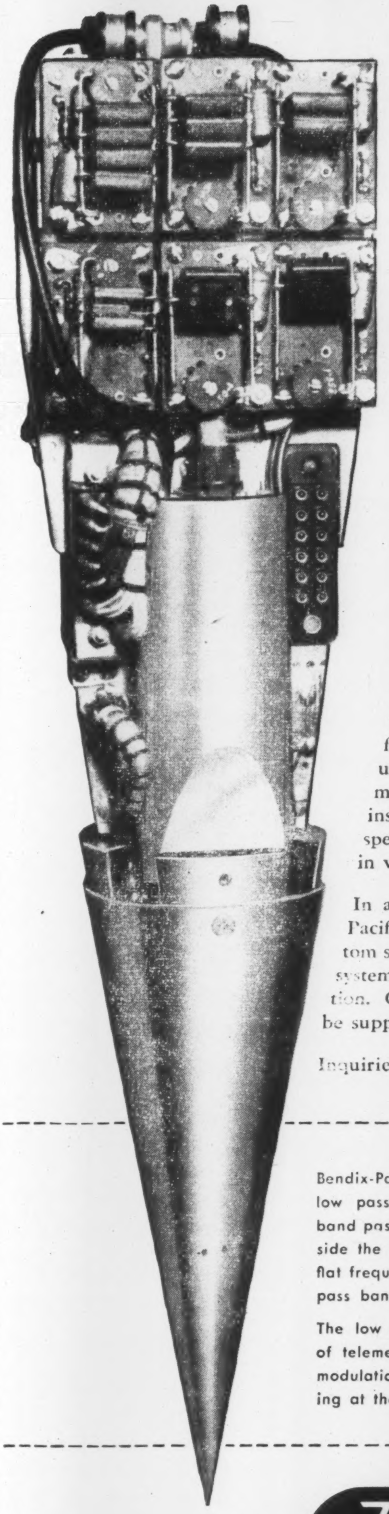
Temperature-compensated Strain Gage

New temperature-compensated type SR-4 strain gage is available for use on Dural and steel; it eliminates use of a second gage for compensation. Two ranges are offered: −50 to 300 F. and 50 to 300 F.—*Baldwin Locomotive Works, Philadelphia* 42, *Pa.*

Mention No. 149 when filling out card.

Explosion-proof Ionization Chamber

New "Model 4SN9A1" ionization chamber is designed for use in Class I, Group D atmospheres. It is pressurized to 15 psi.; battery circuit is opened on loss of pressure. Conducting rubber



BENDIX-PACIFIC TELEMETERING EQUIPMENT PROVIDES COMPLETE INSTRUMENTATION

Bendix-Pacific standard telemetering components can be combined into a compact, highly efficient assembly to meet *exactly* your specified requirements. This extreme flexibility has been accomplished through the use of the building-block principle which permits the purchaser to assemble readily an instrumentation system exactly suited to his specific needs–thus effecting the utmost economy in volume, weight and cost.

In addition to its standard components Bendix-Pacific provides application engineering and custom system design, fabrication and test of complete systems, installation and field test and data reduction. Complete receiving station facilities can also be supplied.

Inquiries are invited.

Bendix-Pacific has recently developed new band pass and low pass filters for telemetering receiving stations. The band pass filters are characterized by high attenuation outside the pass-band by low insertion loss and by extremely flat frequency response and constant phase-shift within the pass band.

The low pass filters are designed to improve the quality of telemetering recordings through the reduction of intermodulation noise and by providing ideal electrical dampening at the input of the recording galvanometer.

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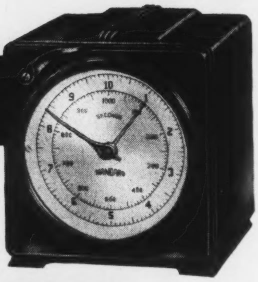
Standard TIMERS



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Model	Scale Divisions	Totalizes	Accuracy
S-100	1 5 sec.	6000 sec.	±.1 sec.
S-60	1 5 sec.	60 min.	±.1 sec.
SM-60	1 100 min.	60 min.	±.002 min.
S-10	1 10 sec.	1000 sec.	±.02 sec.
S-6	1 1000 min.	10 min.	±.0002 min.
S-1	1 100 sec.	60 sec.	±.01 sec.
MST	1 1000 sec.	360 sec.	±.001 sec.
MST-500	1 1000 sec.	30 sec.	±.002 sec.

Write for Timer Bulletin 153

Other Products: Chrono-Tachometers, Custom-Built Laboratory Test and Distribution Panels

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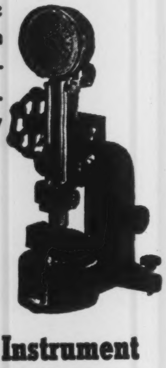

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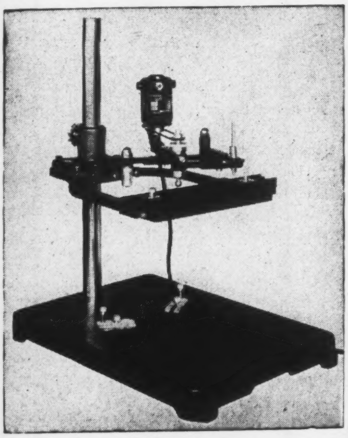
Model 253



A further adaptation of the already proven Mico Engraver, Model 252. Will perform accurate engraving on panels 19-inches wide and of unlimited length. Accommodates work up to 19-inches high.

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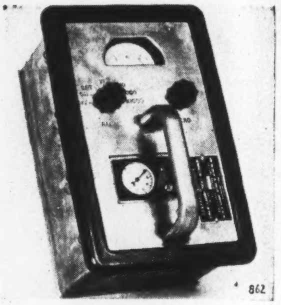


bumpers prevent accumulation of electrostatic charge.—*General Electric Co., Electronics Park, Syracuse, N. Y.*

Mention No. 150 when filling out card.

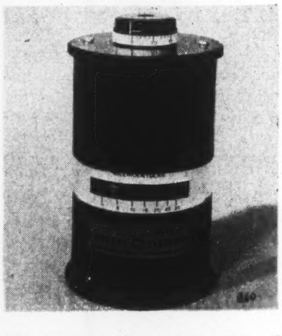
Portable Geiger Counter

New "Model 389 Thyac" portable Geiger counter features regulated plate and high voltages. Any tube with RMA type 1A-82 coaxial base can be used in probe. Beta and gamma radiation are distinguished by use of a shield mounted on probe. Water-proof case weighs 5.5 lbs.—*Victoreen Instrument Co., 3800 Perkins Ave., Cleveland 14, O.*

Mention No. 151 when filling out card.

Radiation Monitor

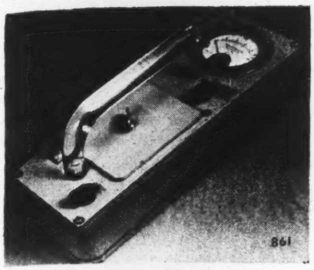
New "Model 4SN11A2" monitor measures total amount of gamma radiation in a given area over a period of time. Unit is self-contained, without batteries or tubes; is charged by inverting.—*General Electric Co., Electronics Park, Syracuse, N. Y.*



Mention No. 152 when filling out card.

Alpha Survey Meter

New "Model 4SN10A2" portable alpha survey instrument utilizes a proportional counting chamber as dectector.

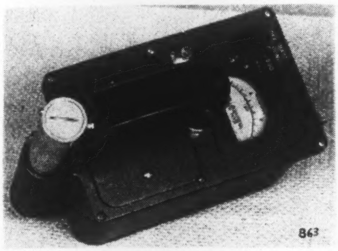


Output is shown on indicator and in headphones. High voltage supply is furnished from batteries.—*General Electric Co., Electronics Park, Syracuse, N.Y.*

Mention No. 153 when filling out card.

Beta-Gamma Survey Meter

New "Model 4SN8A2" beta-gamma survey instrument uses two G-M tubes

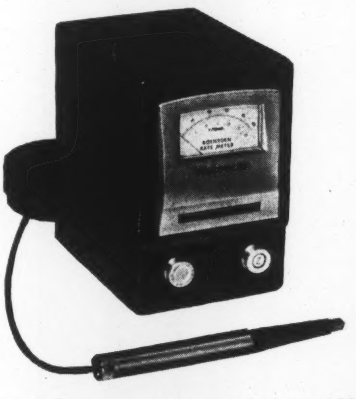


to measure from 0 to 500 milliroentgens per hour in four ranges. Battery voltage is regulated.—*General Electric Co., Electronics Park, Syracuse, N. Y.*

Mention No. 154 when filling out card.

Ratemeter for X-Radiation

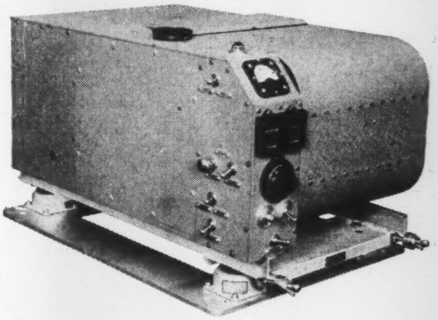
New "Roentgen Ratemeter" measures x-ray beam intensity in roentgens per min. Thimble ion chamber probe is connected to indicating instrument;



one probe covers range of 0 to 100, second probe has range of 0 to 1000 r. per minute.—*Victoreen Instrument Co., 3800 Perkins Ave., Cleveland 14, O.*

Mention No. 155 when filling out card.

Century INDUSTRIAL
RECORDING OSCILLOGRAPH
FOR VIBRATION, TEMPERATURE, STRESS, STRAIN ANALYSIS

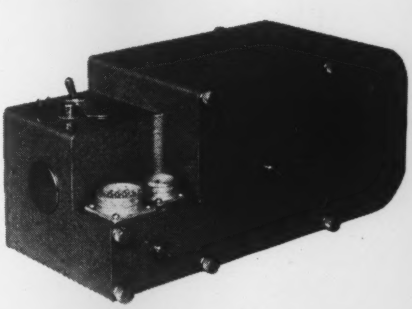


MODEL 408 OSCILLOGRAPH

The Century Model 408 recording oscillograph was designed expressly for airborne and mobile operation. As with all Century products, this oscillograph incorporates the utmost in design and workmanship, along with improved features, yet it remains simple in its operation and maintenance.

FEATURES:
Size: 20" long, 12½" wide, 8⅞" high.
Weight: 60 pounds.
Number of Recording Channels: 6 to 50.
Detachable daylight loading magazine accommodating a roll of paper or film 8" x 200'.
Friction roller type paper drive by governor controlled electric motor with separate motor for takeup drive.
Paper speeds continuously and instantly variable without changing gears or sprockets.
Separate optical system for viewing before or during recording.
Glow tube timing system photographing .01 second and .1 second lines. .01 second lines instantly removable by toggle switch for slower speeds.
Data numbering at beginning of record.
Footage indicator showing amount of paper remaining in magazine.
Automatic record length control.
Trace identification.
Remote control unit.

MODEL 409 OSCILLOGRAPH



The Century Model 409 oscillograph has been designed for recording data where space and weight requirements are limited. This oscillograph has been tested to record faithfully while subjected to accelerations up to 20 G's.

FEATURES:
Size: 5" x 5" x 11".
Weight: 11 pounds.
Cast Aluminum case.
Paper speeds variable ½" to 12" per second.
Detachable daylight loading magazine with a capacity of 3⅝" x 50' paper or film.
2 to 12 individual channels.
Trace identification.
Trace viewing.

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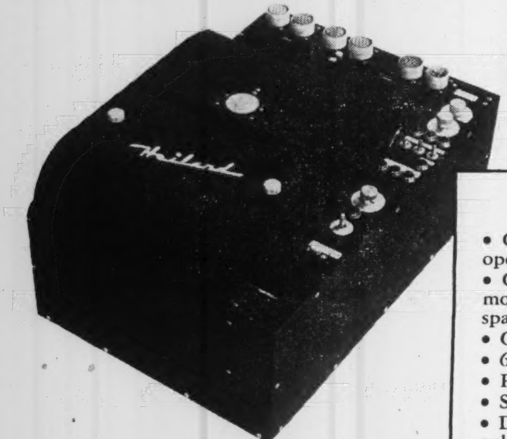

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from operating surface

dependable instruments

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Type A-708...24-channel

FEATURES

- Completely accessible from operating surface
- Compact...can be mounted in a minimum of space...lightweight
- Can be panel mounted
- 6 to 24 channels
- Paper widths 5", 8", 12", 18"
- Simplicity of loading
- Direct monitoring of galvonometer light spots
- Flexibility of operation
- Simultaneous viewing, recording and scanning
- Trace identification...zero mirror...synchronizing reference trace
- Adjustable automatic record length

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Affording complete accessibility from operating surface and requiring only a minimum of space for mounting, the HEILAND A-708 meets the exacting specifications of research and development personnel in aircraft flight testing, laboratory and industrial testing.

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ALUMINUM FOIL SCALES
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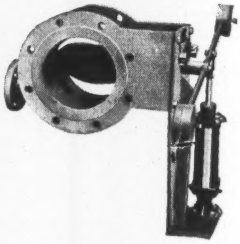
Water Heater Relief Valve

New "Series 3345-33150" relief valves are rated in Btu capacity of water heaters and tanks. Valve and seat are stainless steel, other working parts are corrosion resistant. Opening pressures range from 45 to 150 psi.; body is tapped 0.75 in. inlet, 1 in. outlet.—*McDonnell and Miller, Inc., Chicago* 18, *Ill.*

Mention No. 156 when filling out card.

Off-center Relief Valve

New "No. 780" relief valve is 8 in. diam. and has 150 psi. Std. raised face flanges. A double crank arm with adjustable weights facilitates accurate setting; cylinder shown is a dash pot. On left is a 2-in. flanged outlet for overload relief.—*R-S Products Corp.,* 4600 *Germantown Ave., Philadelphia* 44, *Pa.*



Mention No. 157 when filling out card.

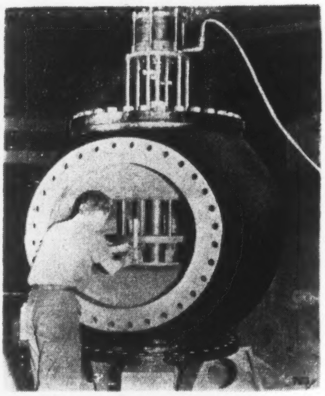
High Pressure Reducing Valve

New "No. 193-135 Type E" reducing valve is improved model for operation to 6000 psi. Main valve and seat ring are Stellite faced. Other internal metal parts are hard chrome plated stainless steel.—*Atlas Valve Co.,* 282 *South St., Newark* 5, *N. J.*

Mention No. 158 when filling out card.

Large Double-ported Valves

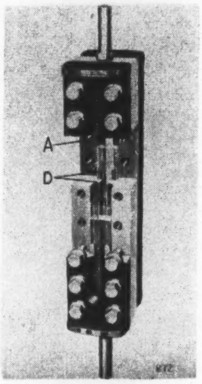
New 36-in. double-ported control valve goes through full travel in 1 sec.; provides tight shut-off. Valve plug guide-posts are equipped with linear type roller bearings. Valve operates in a tonnage oxygen plant.—*Kieley and Mueller, North Bergen, N. J.*



Mention No. 159 when filling out card.

Gaskets for Water-level Gages

New "Frelon" gaskets are being supplied in maker's high-pressure, flat-glass, water-level gages. Frelon gaskets



in grooves of gage insert body are shown at D in illustration.—*Yarnall-Waring Co., Mermaid Lane, Philadelphia 18, Pa.*

Mention No. 160 when filling out card.

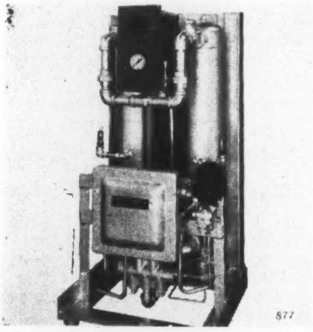
Infra-red-pass Filters

New "Type C" filters pass only radiation in near infra-red, between 1.0 and 3.3, and 3.4 and 5.8 microns, with efficiency up to 70 percent. Special forms of filter transmit only one of two pass-bands above. Filters can operate up to 250 F. continuously—*Polaroid Corp., Cambridge 39, Mass.*

Mention No. 161 when filling out card.

Compressed-air Dehydrator

New "Model 50 EIA" automatic dehydrator has a capacity of 50 scfm., with an outlet dew-point of -40 F. One chamber dries gas for six hr. while



second chamber is reactivating and cooling; "Sovabead" dessicant is used. Moisture indicator is located on front panel. Unit illustrated is for Class I, Group D atmospheres.—*Industrol Corp., 472 Westfield Ave., Roselle Park, N. J.*

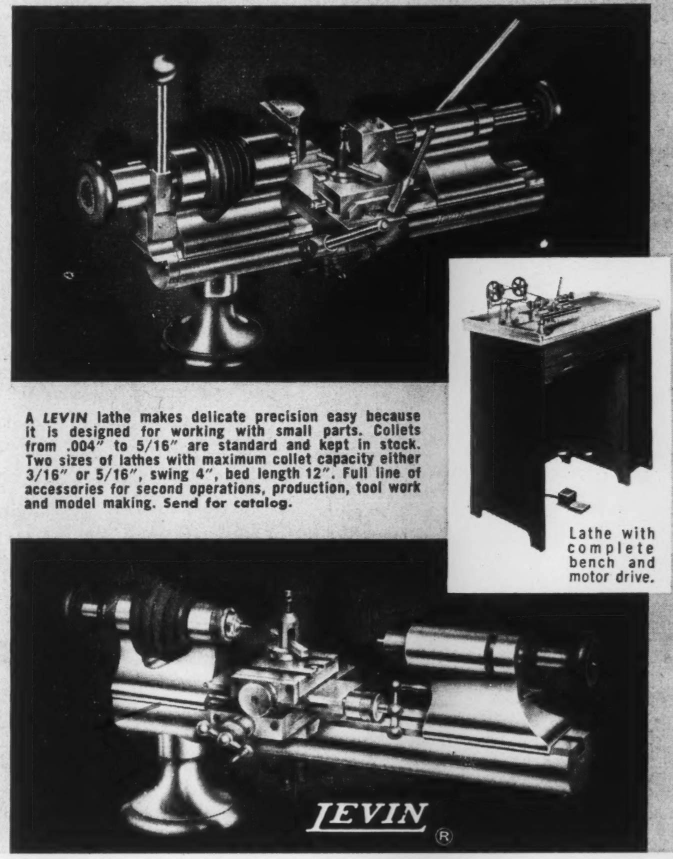
Mention No. 162 when filling out card.

Infra-red Polarizer

New "Type HR" infra-red polarizer operates from 0.8 to 2.5 microns. Units are available laminated in glass or plastic; are resistant to ultra-violet

HOLD A ROD .004" IN DIAMETER

WITH COMPLETE ACCURACY



A *LEVIN* lathe makes delicate precision easy because it is designed for working with small parts. Collets from .004" to 5/16" are standard and kept in stock. Two sizes of lathes with maximum collet capacity either 3/16" or 5/16", swing 4", bed length 12". Full line of accessories for second operations, production, tool work and model making. Send for catalog.

Lathe with complete bench and motor drive.

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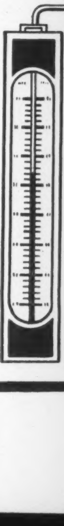

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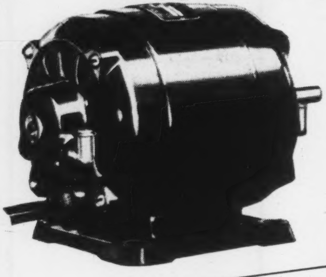

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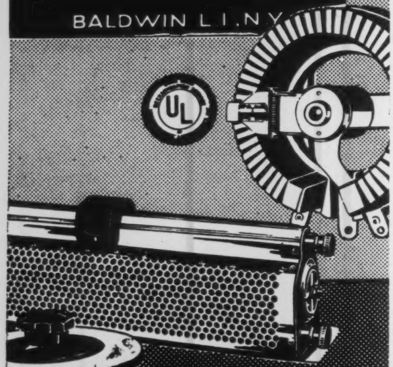

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radiation, and weathering; can operate up to 150 F. continuously. Transmission for a single polarizer is 38 percent.—*Polaroid Corp., Cambridge 39, Mass.*

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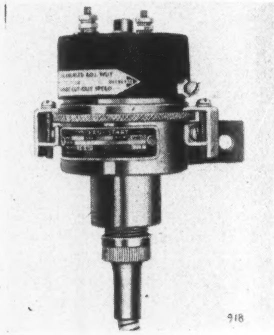
Overspeed Governor

New "Models GFA and GFM" overspeed governors feature sealed ball bearings, and a take-off for flexible-shaft tachometer drive. Units are all metal; shut-down speed can be adjusted while running. Weight is 3 lbs. —*Sychro-Start Products, Inc., 1046 W. Fullerton Ave., Chicago 14, Ill.*



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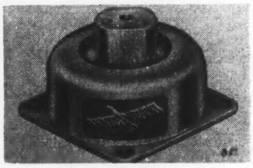
Vibration Isolators

New "All-Metl" vibration isolators use springs and knitted wire pads to absorb shock and vibration. Mount is 2.375 in. square by 1.3 in. high. Standard and special bases available.—*Barry Corp., 173 Sidney St., Cambridge 39, Mass.*



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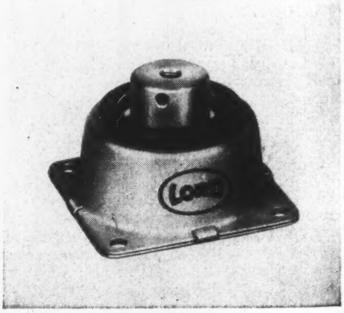
Vibration Mounts for Wide Ambient Range

New "Temproof" vibration control mounting operates in ambients from –80 to 250 F. They are for use with JAN-C-172A equipment; built-in friction dampers prevent excessive motion



at resonant frequencies. Mounting drift has been reduced to a negligible amount, and unit functions over a wide range of loadings, maker states.—*Lord Mfg. Co., Erie, Penna.*

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Laboratory Glassware Service

New complete service offered by glass blowing laboratory includes fabrication, modification, or repair of glassware items of unusual or intricate design (vacuum tubes, pumps, columns, stills, condensers, micro-distillation apparatus, etc.). Finished pieces are strain-checked by polariscopic examination.—*Chem. Products Div., Phillips Petroleum Co., Bartlesville, Okla.*

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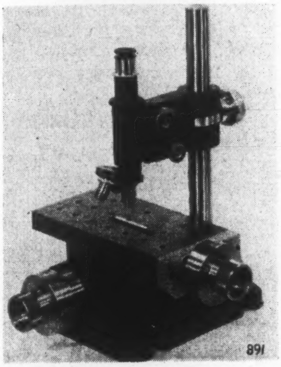
Tool-maker's Microscope Base

New tool-maker's microscope base has hold-down ears for mounting on machine tables. Unit has longitudinal travel of 6 in., and transverse travel of 4 in.; calibrated drums read direct to 0.0001 in. A variety of optical combinations can be mounted on post provided.—*Erb & Gray, 854 S. Figueroa St., Los Angeles 17, Calif.*



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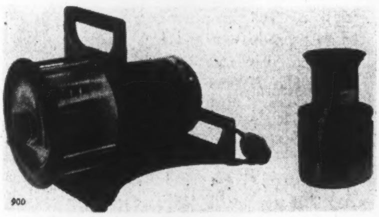
Small Mercury Cleaning Unit

New small mercury cleaning unit handles 5 lb. lots; is similar to maker's large models. Mercury is aerated by agitation, oxidizing base metal contaminants. Precipitates are separated from metal by filter operating on gold adhesion principle. Aerator operates on 115-v. 60-cps. line.—*Bethlehem Apparatus Co., Front & Depot Sts., Hellertown, Pa.*



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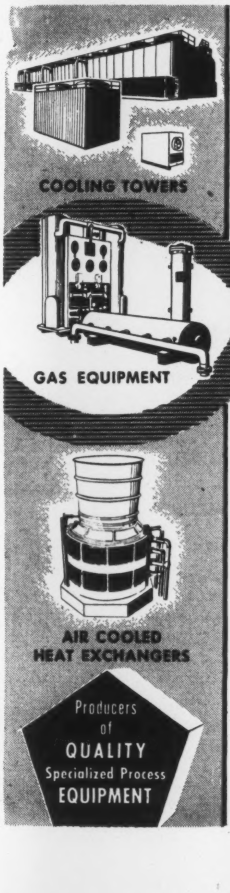
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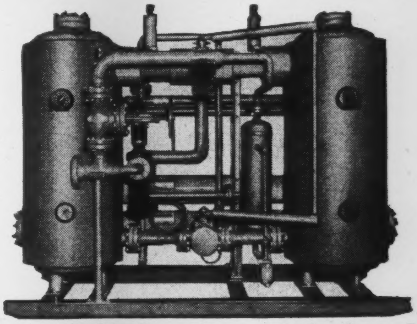

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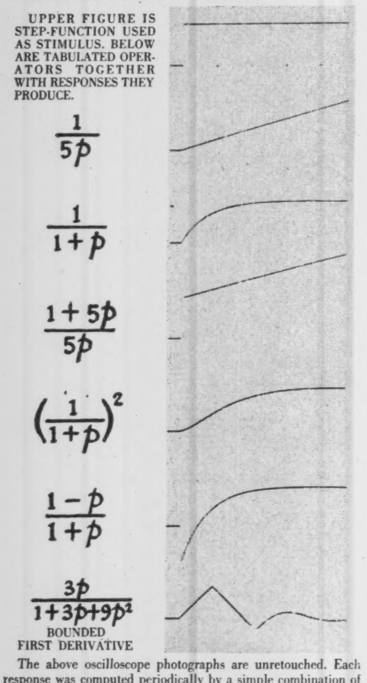
The transients initiated by specific stimuli, like a common language, serve to relate and identify dynamic structures among technologies which are otherwise diverse.

Under transformation of the variables, how many different basic systems are represented by the responses below?

In this case the ordinate scale is ten volts; the unit for the concurrent time abscissae is 0.0004 seconds.



The above oscilloscope photographs are unretouched. Each response was computed periodically by a simple combination of GAP/R Electronic Analog Computor Components. Phenomena of any complexity, non-linear as well as linear, may be embodied and represented in this manner. Quantitative studies are speedily pursued through the use of this ultra-modern tool of synthesis.

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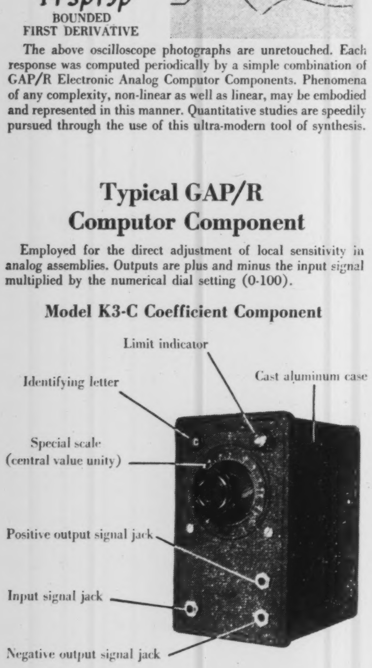
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Identifying letter
Cast aluminum case
Special scale (central value unity)
Positive output signal jack
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Negative output signal jack

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STANDARDS FOR ELECTRICAL MEASUREMENT

Continued from page 37

Special four-terminal standard resistors, constructed so as to have negligible skin effect and a known computable inductance (hence a known phase angle), are used to measure the ratio and phase angle of transformers up to 2500 amperes with a specialized form of a-c. potentiometer. Beyond this limit, up to 12,000 amperes, the unknown transformer is compared with a multirange standard transformer, which is calibrated on its lower ranges by the use of standard resistors and is then used as a standard on its higher ranges. Careful study of this standard transformer has given assurance that its various ranges bear simple integral ratios to one another.

Similarly, the extension of the a-c. voltage scale above 150 volts is, in practice, based upon the use of voltage transformers. A special shielded resistor, capable of operating at 30,000 volts, is used to measure the effective ratio and phase angle of voltage transformers up to this limit and also to check the performance of standard multirange transformers when they are connected for 25,000 volts. These multirange transformers can then be connected for 50,000 or for 100,000 volts and used as standards at these latter ratings. A still larger standard transformer is calibrated with its coils in parallel at 100,000 volts and used with its coils in series as a standard up to 250,000 volts.

For all this testing and calibration work, other than that performed for the Federal and State governments, the law requires the Bureau to charge an appropriate fee.[3] These fees are high enough to avoid subsidized competition with private testing laboratories but are low enough to make it possible for all industrial laboratories to attain high accuracy where desirable in their work. In any event, the cost to both government and industry of the Bureau's electrical standardization services is slight in comparison with the savings to the Nation which result from the program. For example, the electrical power industry has now grown to the point where the annual bill for electric energy is approximately four billion dollars. If there were a consistent error of one percent in the standards used at the Bureau to calibrate the electric meters with which the industry calibrates its customer meters, either the power companies or the consumers would lose forty million dollars each year. Yet the cost of maintaining the Bureau's service in this field is much less than one percent of the discrepancy.

The Bureau is currently making efforts to meet the demand for ever-increasing volume and complexity in electrical standardization work. Techniques are being developed for the more accurate measurement of man-made lightning—very-short-duration surges of high current—which are coming to be

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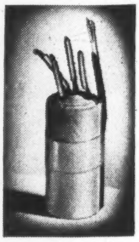

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used by electrical manufacturers to test high-voltage equipment. Methods are also being worked out for the more rapid and economical checking of watt-hour meters; the testing of the very high resistances now used in measuring ion currents and other radiation effects; and the testing at 400 and 1000 cycles per second of instruments and instrument transformers for use on aircraft and in induction furnaces for heat-treating metals.

REFERENCES

(1) National Bureau of Standards Circular 475, "Establishment and Maintenance of the Electrical Units," by F. B. Silsbee, available from the U. S. Government Printing Office at 25 cents a copy.

(2) "Standards of Very Small Capacitance" (article communicated by the National Bureau of Standards). *Instruments*, Vol. 21, June 1948, page 544.

(3) For fees and other information on the testing and calibration program, see National Bureau of Standards Circular 483, "Testing at the National Bureau of Standards," available from the U. S. Government Printing Office at 25 cents a copy.

TECHNICAL SOCIETIES

BRITAIN'S PHYSICAL SOCIETY EXHIBITION

The Physical Society's 35th Annual Exhibition of Scientific Instruments and Apparatus will be held from Friday, April 6, to Wednesday, April 11, 1951, excluding Sunday.

This year both the Royal College of Science Main Building, Imperial Institute Road, and the Huxley Building, Exhibition Road, (opposite Science Museum) will be used. On Friday morning the Exhibition will be open for Members of the Society and the Press only.

The exhibition affords one of the most important displays of scientific achievement which is held in Great Britain, and is unique in showing side by side the work of academic scientists, commercial instrument makers and research workers in Government and other laboratories.

Discourses will be delivered by eminent scientists during four days of Exhibition.

A Handbook of the Exhibition, containing full descriptions of all exhibits, will be obtainable from the Physical Society in early March.

SOCIETY FOR APPLIED SPECTROSCOPY

The February meeting of the Society for Applied Spectroscopy will be held on Tuesday, the 6th: 6:00 p.m. Informal dinner, Tosca's, 118 Fulton St. 8:00 p.m. Regular meeting, Socony-Vacuum Training Center, 63 Park Row, New York.

Papers to be presented: 1. Simultaneous Determination of Pyrilamine Maleate and Quinine, by J. D. Neuss, G. E. Herpich and H. A. Frediani, Merck & Co., Inc., Rahway, N. J. 2. Application of Raman Analyses to Petroleum Fractions, by B. F. Dudenbostel, Jr., Esso Labs, Linden, N. J. 3. A Spectrograph Source Control System, by Robert W. Murphy, Socony-Vacuum Labs, Brooklyn, N. Y.

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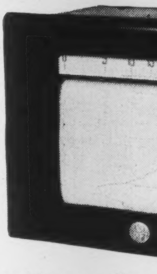

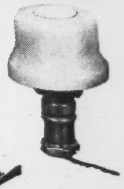

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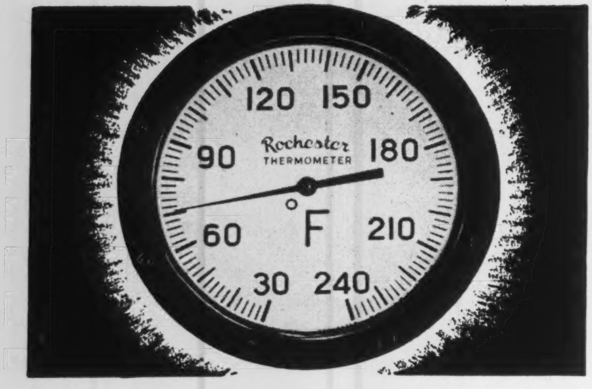

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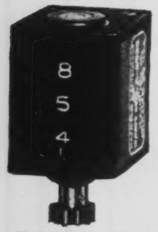
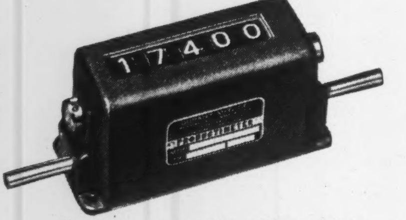


High-speed, non-reset "Y" type counter for building into radar instruments.



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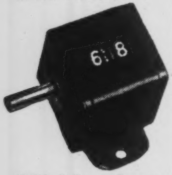

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POWER PLANT CONTROLS

Continued from page 57

over the entire range of the boiler, that is from light load to full load. Unfortunately, this ideal operating characteristic has never been fully materialized on a universal commercial basis.

Therefore, systems have been worked out whereby the desired steam temperature from a boiler is had on light loads by the proper selection of superheating surfaces and the high steam temperature encountered at the upper load limits is reduced by cooling all or part of the steam.

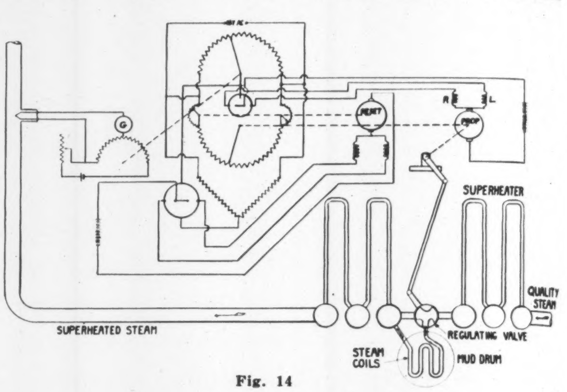

Fig. 14

One method for accomplishing this purpose is the passing of a portion of the superheated steam through a cooling coil situated in the lower water drum of the boiler and mixing this cool steam with the other uncooled steam. The desired outlet steam temperature is controlled automatically by an electronically-operated control valve. Such an arrangement is shown in Fig. 14.

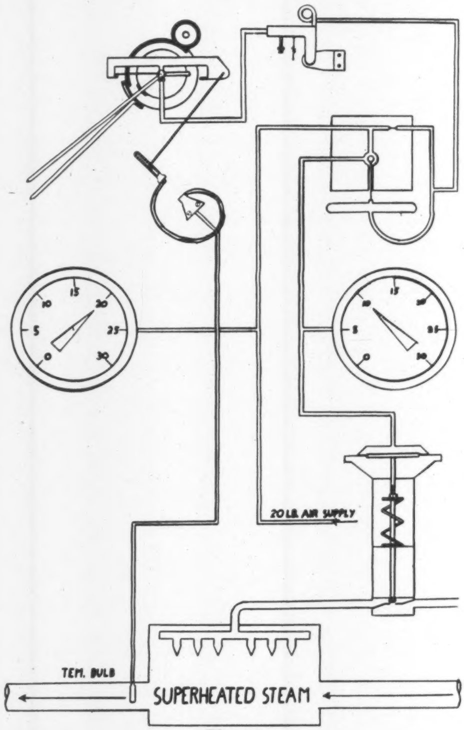

Fig. 15

Another method consists of merely passing the superheated steam through a chamber into which relatively cool water is sprayed. The desired temperature is automatically accomplished by a gadget that controls the amount of water sprayed into the chamber. Such an arrangement is shown in Fig. 15.

Another method used for obtaining the desired temperature is to by-pass a portion of the products of combustion around the superheater surfaces. Such a method is shown in Fig. 16. It will be noted that this arrangement affects the boiler efficiency even though an economizer or air preheater is used. The installation shown is manually operated, however this can be made automatic by any of a number of controllers manufactured at the present time.

STEAM PRESSURE REGULATORS

In most power plants there is little use for automatically controlling steam pressure other than on the boiler. In some instances, however, a lower steam pressure is desired for feeding the auxiliary equipment. This supply of steam usually is obtained by passing a boiler steam pressure through a spring- or air-operated pressure reducing valve. The types and operating details of the pressure reducing valves are too numerous to mention.

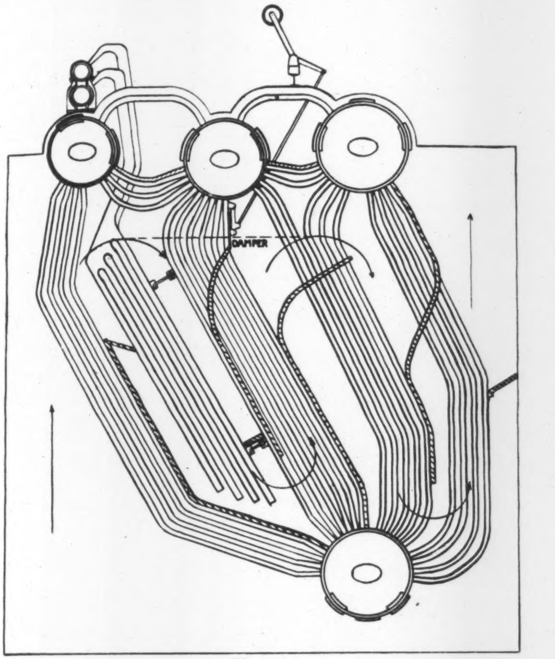

Fig. 16

ACKNOWLEDGEMENTS

In presenting this paper I am deeply indebted for illustrations used from *Power* and other magazines. Also to the members of our Advertising Department, Power Department Stenographers, Nueces Bay Power Station, Nueces Bay Laboratory and Miss Barbara Hesse for the preparation of the various sketches and typing.

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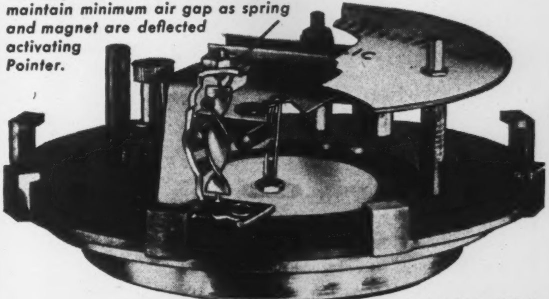

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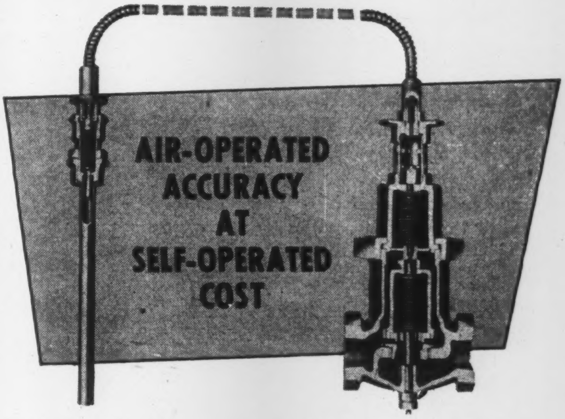

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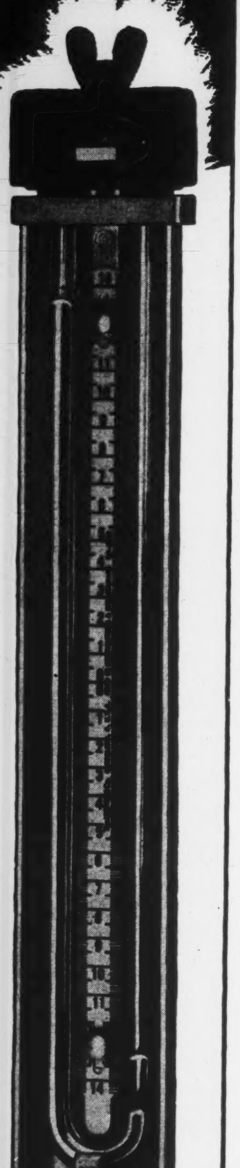

Measuring directly in inches or millimeters of mercury

This new instrument is proving notably popular in various industries for the measurement of *absolute pressures* from one millimeter of mercury to the equivalent atmospheric pressure.

It is a U-tube manometer with one leg sealed and filled with mercury; the other open tube leg connects to the source of pressure to be measured. The tube is removable and can be easily replaced, when necessary, with another tube, mercury filled, shipped directly to location.

Of simple design—no cams, gears, levers—the Meriam U-Type Absolute Pressure Gauge is accurate and dependable. It is strongly built for lasting service. The gauge head fastens to the body by a single wing nut. Available in wall or flush front mounting styles. The wall mounted unit, illustrated, is Model C-1142 WM and is fully described in catalog sheet C-1142 WM—available upon request.

THE MERIAM INSTRUMENT CO.
10958 MADISON AVENUE
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★ **MERIAM** ★
Instruments
ESTABLISHED 1911

MANOMETERS, METERS AND GAUGES FOR THE ACCURATE MEASUREMENT OF PRESSURES, VACUUMS AND FLOWS OF LIQUIDS AND GASES

1001 GAUGES to choose from

The combinations of styles, types, mountings, ranges and functions of Marsh Gauges are almost endless; but they all have one trait in common: Each is best for the service for which it is recommended. Write today for the new Marsh Catalog covering the broad Marsh line. Let us prove that Marsh is the gauge for your product, whether you need a few or thousands.

Marsh Instrument Co.
Sales affiliate of
Jas. P. Marsh Corp.
Dept. 42, Skokie, Ill.

MARSH

A SUPERIOR DETECTOR for INFRA-RED SPECTROSCOPY

Golay PNEUMATIC DETECTOR

Among the characteristics that render the Golay Detector superior to other types of detectors for use in infra-red spectroscopy are:

1. An effective sensitive area 3/32" in diameter.
2. Sensitivity of 6 x 10-11 watts RMSENI when used with "chopped beam" method and with recording time constant of 1.6 second.
3. Uniform sensitivity from the ultra-violet through the visible and the entire infra-red, and up to the micro-wave region.

Write for EPLAB Bulletin No. 10

THE EPPLEY LABORATORY, INC.
Scientific Instruments
NEWPORT • RHODE ISLAND • U. S. A.

Volume 7 January 1951 Number 1

INSTRUMENT SOCIETY OF AMERICA Journal

Officers

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Vice President: W. A. Wildhack

Treasurer: G. R. Feeley

Secretary: Richard Rimbach

ISA National Office: 921 Ridge Ave.,
Pittsburgh 12, Pa.

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TABLE OF CONTENTS

Section Secretaries Meeting Data and Programs 2
1951 ISA National Officers 3
1950 Show Attendance 3
A New Feature at Houston Exhibit 4
ISA Employment Service 5
Employment and the Instrument Industry 5
Railway Signaling by G. W. Baughman 6
New York Regional Conference 12

THE SECRETARY'S PAGE

Richard Rimbach

WITH the New Year, the new officers will take up their duties. These men are taking over the management of the Society under very difficult times and they are looking to the membership for every possible assistance.

As you know the management of the Society is divided into three departments each under the direct supervision of a Vice-President.

The *Membership Relations Division* is the responsibility of Nelson Gildersleeve and the committees in this division are as follows:

Coordinating Committee
Employment Committee
Historical Committee
Instrument Manufacturer's Committee
National Defense Committee
Sections and Membership Committees

"Nelson" has always been interested in membership, having been the first chairman of the Sections and Membership Committees. We still want the members to do their utmost to increase the membership to 5000 by April.

The *Operating Division* is in the very capable hands of "Tiny" Isenhour. This division is made up of the following committees:

Constitution and Rules and Procedures Committees
Finance Committee
Meetings Committee
Publications Committee

The *Technical Division* under the guidance of "Bill" Wildhack has the following committees:

- Committee for Analysis Instrumentation
- Committee on Instrumentation for Production Processes
- Instruments for Inspection and Gaging Committee
- Instrument Maintenance and Operation Committee
  - Instrument Calibrating Techniques Sub-Committee
  - Instrument Installation Practices Sub-Committee
  - Instrument Maintenance Practices Sub-Committee
  - Instrument Mechanic Training Sub-Committee
  - Instrument Shop Layouts and Shop Equipment Sub-Committee

Continued on page 93

Section Secretaries, Meeting Data and Programs

AKRON
Fred Appel, 932 Columbia Ct., Barberton, Ohio. Tel: SH 3440

Fourth Tuesday, Meeting at 7:30 P. M., Akron Y.W.C.A.

Jan. 23, "Principles of Automatic Control," ISA color and sound film by G. F. Akins, J. Kowalski, Eastman Kodak Co.

ALBUQUERQUE
E. J. Burda, Sandia Corp., P. O. Box 5800, Albuquerque, N. Mex. Tel: 5-5511

First Monday, Meeting at 8:00 P.M., Science Lecture Hall, Univ. of N. M.

ARUBA
K. H. Walker, P. O. Box 389, c/o Lago Oil & Transport Co., Ltd., Aruba, N.W.I.

First Tuesday, Meeting at 7:15 P. M., Engr's Club.

ATLANTA
H. Kockritz, Fischer & Porter Co., 84 Peachtree St., Atlanta, Ga. Tel; CY 1269

Fourth Monday, Meeting at 7:45 P.M., Ga. Institute of Technology.

BALTIMORE
W. A. Dickinson, 2716 Dunbrook Ct., Baltimore 22, Md. Tel. Dundalk 2272J

Second Friday, Meeting at 8:00 P.M., Engr's. Club of Baltimore.

BATON ROUGE
John Q. Bass, 1517 Longwood Dr., Baton Rouge. La. Tel: 3-0283

Meeting monthly, no definite time, L.S.U. Physics Bldg.

BOSTON
Stephen E. Lord, 60 Braintree Ave., Quincy 69, Mass. Tel: MA 9-1066

Last Wednesday, Dinner at 6:30 P. M., Meeting at 7:00 P.M., 99 Club, 99 State St.

CALIFORNIA
D. C. Duncan, Helipot Corp., 916 Meridian Ave., S. Pasadena, Calif. Tel: SY 4-8439

Second Wednesday, Dinner at 6:30 P. M. Meeting at 8:00 P.M., Carolina Dines.

CENTRAL ILLINOIS
Thomas A. Carroll, 721 Hurlburt St., Peoria 6, Ill. Tel.: Peoria 4-8909

First Wednesday, Dinner at 6:30 P.M., Meeting at 7:30 P.M.

March 7, "Principles of Automatic Control," ISA Color & Sound film by G. F. Akins, J. Kowalski, E. Kodak Co.

CENTRAL INDIANA
Richard F. Rieman, 3550 Euclid St., Indianapolis, Ind. Tel. CH 7462

First Tuesday. Meeting at 7:30 P. M.

CENTRAL NEW YORK
Karl W. Robertson, Minneapolis-Honeywell Reg. Co., 121 W. Onondaga St., Syracuse, New York.

CHARLESTON
Clayton A. Williams. 303 E. 9th St., Belle, W. Va. Tel: 927871

First Monday, Dinner at 6:15 P.M., Meeting at 8:00 P.M., Kanawha Hotel.

Feb. 5, "Instruments for Industry," L. Van Blerkom, Tagliabue Div., Weston Inst. Corp.

March 5, "Telemetering," W. E. Rufleth, Bristol Co.

CHICAGO
Floyd E. Ertsman, Rm. 1420 Fisher Bldg., 343 S. Dearborn St., Chicago 4, Ill. Tel: WE 9-0686

First Monday, Dinner at 6:30 P. M., Meeting at 8:00 P. M., Shoreland Hotel.

Feb. 5, "Spectrophotometry—Mass Spectrograph," Dr. Grubb, Std. Oil Co., Indiana.

March 5, "Basic Errors in Testing," W. A. Wildhack, Natl. Bur. Stds.

CHINA LAKE
A. H. Staud, 1004 Michelson Lab., USNOTS, China Lake, Calif. Tel: 77882

Fourth Thursday, Meeting at 8:00 P.M., Michelson Lab. USNOTS.

CINCINNATI
L. W. Greene, 181 Market St., Aurora, Ind.

Second Monday, Meeting at 8:00 P.M., Eng'r. Society Hqs.

CLEVELAND
A. E. Ehrke, 1732 East 291st St., Wickliffe. Ohio. Tel: WI 3-1036

Fourth Wednesday, Dinner at 6:30 P.M., Meeting at 8:00 P.M., Cleveland Eng'r. Society, E. 19th St.

COLUMBUS
W. C. Myers, c/o Battelle Memorial Institute, 505 King Ave., Columbus, Ohio. Tel: UN 3191, Ex. 248

Third Thursday, Meeting at 8:00 P.M., Battelle Auditorium

CUMBERLAND
Clyde Babst, 225 Cecilia St., Cumberland, Md. Tel: 583-W

Tuesday after Fourth Monday, Dinner at 6:30 P.M., Meeting at 8:00 P.M., Algonquin Hotel.

DETROIT
A. W. Brueckner, 5556 S. Clarendon Ave., Detroit 4, Mich. Tel: TYler 6-9511.

Third Tuesday, Dinner at 6:30 P.M., Meeting at 8:00 P.M., Rackham Bldg.

Feb. 20, "The Technique of High Speed Photography," W. G. Moline, Ford Motor Co.

EASTERN NEW YORK
W. R. McKegg, c/o Gen. Engrg. & Consulting Lab., G. E. Co., Schenectady, N. Y.

First Tuesday, Dinner at 6:30 P.M., Meeting at 8:00 P.M.

GULF COAST
W. N. Sloan, E. I. Du Pont de Nemours & Co., Orange, Texas. Tel: 8411 Ext. 444

Third Tuesday. Meeting at 7:30 P.M., Lamar College, Beaumont, Texas.

HOUSTON
I. K. Farley, 2123 Travis St., Houston, Texas, Tel: Charter 2511.

Last Monday, Meeting at 8:00 P.M., Engineers Club.

KANSAS CITY
L. E. Oberhelman, Standard Oil Co., Sugar Creek, Mo. Tel: MU 1227

First Tuesday, Meeting at 7:30 P.M., Univ. of Kansas City.

Feb. 6, "Gas Analysis Instrumentation," N. W. Hartz, Mine Safety Appliances Co.

March 6, "Coordinated Control Systems and Graphic Panels," A. F. Sperry, Panellit, Inc.

LOUISVILLE
H. C. Scherffius, 980 Palatka Rd., Louisville 8, Ky. Tel: Franklin 1265

Fourth Tuesday, Meeting at 8:00 P.M., Seagram Auditorium.

MONTREAL
S. J. Mizuhara, 1075 Allard, Verdun, Quebec, Canada. Tel: TR 3252

Last Monday, Meeting at 8:00 P.M. Mechanics' Institute.

NEW JERSEY
Fred L. Crabbe, Malcolm W. Black & Co., Inc., 41 East 42nd St., New York 17, N. Y. Tel: Vanderbilt 6-2960.

First Tuesday, Dinner at 6:00 P. M. Meeting at 8:00 P.M., Essex House, Newark.

Feb. 6, "Radioactive Measurement Apparatus," W. C. Nusbaum, Tracer Lab.

March 6, "Pneumatic Computing Relays and Their Place in Control Circuits," M. J. Boho, Hagan Corp.

April 3, "Panel Board Design," Symposium beginning with luncheon at noon.

NEW ORLEANS
W. H. Haney, 2927 Music St., New Orleans 22, La.

No Regular Date, Meeting at 8:00 P.M.

NEW YORK
F. B. Leslie, 8856 Commonwealth Blvd., Bellerose 6, N. Y. Tel: FI 7-0645

Last Monday, Dinner at 6:00 P.M., Meeting at 7:45 P.M., Henry Hudson Hotel.

Jan. 26, 27, Annual Regional Conference, Hotel New Yorker. Four Sessions on Modern Process Controllers. Meetings from 9:00 A.M. to 5:00 P.M. Dinner on Friday Evening.

NIAGARA FRONTIER
Mrs. James L. Martin, 697 Potomac Ave., Buffalo 22, N. Y. Tel: GR 1450

Fourth Monday, Dinner at 6:00 P.M., Meeting at 8:00 P.M., N. Y. State Inst. of Arts and Sciences, Buffalo.

Jan. 22, "Automatic Control for Steam Boilers," P. S. Dickey, Bailey Meter Co.

Feb. 26, Inspection Trip to Westinghouse plant at Cheektowaga, N. Y.

NORTH TEXAS
R. E. Byers, 6000 Lemmon Ave., Dallas 9, Texas

NORTHERN CALIFORNIA
S. D. Stillson, 1324 Everett St., El Cerrito, Calif. Tel. Becon 2-7139

Third Monday, Meeting at 8:00 P.M., East Bay Area.

Feb. 19, San Fran., "Temperature Measurements," Herman Held, Weston Elec.

March 19, "Gyroscopic Principles & their Uses," N. Thompson, Sperry Gyroscope, East Bay.

NORTHERN INDIANA
J. Baum Beckman, 547 N. Waller Ave., Chicago 44, Ill. Tel: ES 8-7776

First Wednesday, Meeting at 7:30 P.M., Whiting Community Center, Whiting, Ind.

OAK RIDGE
John H. Clark, 230 Canton Hall, Oak Ridge, Tenn. Tel: 5-9142

First Wednesday, Dinner at 6:30 P.M., Meeting at 7:30 P.M., Oak Terrace.

ONTARIO
John W. Huether, 311 Southerland Dr., Leaside, Ontario, Canada. Tel: HU-7114

Third Thursday, Meeting at 8:00 P.M. Friendship Hall, College St. United Church, Toronto

PANHANDLE
R. E. Harris, 228 Mays Bldg., Amarillo, Texas. Tel.: 31434.

Third Tuesday, Meeting at 8:00 P.M.

PHILADELPHIA
C. W. Wood, 6908 Market St., Upper Darby, Pa. Tel: Clearbrook 9-3959

Third Wednesday, Meeting at 8:00 P.M., Bellvue Stratford Hotel.

PITTSBURGH
Miss Louise Suckfield, P.O. Box 2038, Pittsburgh 30, Pa. Tel: HI 1-1800

Fourth Monday, meeting jointly with the Technical Committee on Inspection and Gaging. Dinner at 6:30 P.M., Meetings at 8:00 P.M., Roosevelt Hotel.

Jan. 22, "Instrumentation for the Operating Engineer," J. S. Leslie, Leslie Co., Inspection Committee Speaker: James Mulligan, Mesta Machine Co.

Feb. 26, "An Improved Pneumatic Control System," R. E. Clarridge, Taylor Inst. Co. Inspection Committee Speaker: N. Bowers, American Petroleum Institute.

PRESQUE ISLE
Edwin P. Schuwerk, 445½ Halley St., L. P., Erie, Pa. Tel: 2-3349

Fourth Tuesday, Meeting at 8:00 P.M., G. E. Community Center, East Lake Rd., Erie, Pa.

RICHLAND
R. A. Nederhood, 2003 Trippe, Richland, Washington. Tel. 5-4442

Second Wednesday, Meeting at 7:30 P.M., American Legion Hall.

ROCHESTER
R. C. Schwarz, Jr., 1201 Granite Bldg., Rochester 4, N. Y. Tel: Monroe 4610R

Fourth Tuesday, Meeting at 8:00 P.M., Univ. of Rochester, Physics Lecture Hall.

SARNIA
J. J. Connors, 272 Elgin St., Sarnia, Ontario, Canada. Tel: 1970 W

Second Friday, Meeting at 8:00 P.M., Moose Hall.

SOUTH MICHIGAN
W. J. Sprau, 2509 S. Rose St., Kalamazoo, Mich. Tel: 4-7012.

Fourth Wednesday, Dinner at 6:30 P.M. Meeting at 8:00 P.M., Chicken Charlie's, Kalamazoo.

SOUTH TEXAS
H. C. Givens, La Gloria Corp., P.O. 637, Falfurrias, Texas. Tel: 122-W

First Thursday. Meeting at 7:30 P.M., Garner Aircraft Instrument School.

ST. LOUIS
W. G. Lee, 4710 Delor St., St. Louis 16, Mo. Tel: FL 8516

First Wednesday, Meeting at 8:00 P.M., Engineer's Club of St. Louis.

Feb. 7, "Gas Analysis Instrumentation," N. W. Hartz, Mine Safety Appliances Co.

March 7, "Coordinated Control Systems and Graphic Panels," A. F. Sperry, Panellit, Inc.

TOLEDO
Morris L. Conner, 925½ Sherman St., Toledo, Ohio. Tel: MA 9403

Third Tuesday, Meeting at 8:00 P. M., Service Bldg., Toledo Edison Co.

March 3, "Principles of Automatic Control," ISA Color-Sound film.

TENNESSEE
N. M. Taylor, 16 Edgewood, Kingsport, Tenn. Tel: 3338J

No definite night, Dinner at 6:45 P.M., Meeting at 8:00 P.M., Hall's Dining Rm., Bristol Hwy., Kingsport.

TULSA
J. J. Fox, Phillips Petroleum Co., Phillips Bldg., Bartlesville, Okla. Tel: 6600 Ext. 501.

First Monday, Meeting at 7:30 P.M., Engineering Bldg., Tulsa Univ.

Feb. 5, "Gas Anlysis Instrumentation," N. W. Hartz, Mine Safety Appliances Co.

March 5, "Coordinated Control Systems and Graphic Panels," A. F. Sperry, Panellit, Inc.

TWIN CITIES
Alden Hine, c/o Pinkney & Hine, 552 Plymouth Bldg., Minneapolis 3, Minn. Tel.: Lincoln 0523.

Fourth Tuesday, Dinner at 6:30 P.M. Coffman Memorial Union, U. of Minn.

WASHINGTON
Raymond E. Miller, 20-224 Naval Ord. Lab., White Oak, Md. Tel: JU 7-6742

Third Monday, Meeting at 8:00 P.M., P. E. P. Co. Auditorium.

WAYNE COUNTY
Robert Karr, 2455 Biddle Ave., Wyandotte, Michigan. Tel. 0167J

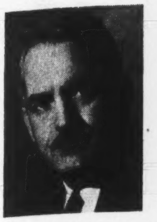
Third Monday, Meeting at 8:00 P.M., Larson's Cafe, Lincoln Park, Mich.

Feb. 20, "Principles of Automatic Control," ISA Color-Sound film.

WILMINGTON
Dean Valentine, 34 N. Hill Drive, West Chester, Pa. Tel: 0293W

Third Tuesday, Meeting at 8:00 P.M. Harlan Public School, Wilm.

1951 ISA NATIONAL OFFICERS



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Porter Hart
First Vice President

G. R. Feeley
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R. J. Rimbach
Exec. Secretary

N. Gildersleeve
Vice-President
Supervising
Membership Relations
Division

N. L. Isenhour
Vice-President
Supervising
Operating Division

W. A. Wildhack
Vice-President
Supervising
Technical Division

Continued from page 91

- Instrumentation for Testing Committee
- Instrumentation for Transportation Committee
- Recommended Practices Committee
  - Procedures Sub-Committee
  - Thermocouples and Thermocouple Extension Wire Sub-Committee
  - Flowmeter Installations Sub-Committee
  - Control Valve and By-Pass Installations Sub-Committee
  - Instrumentation Flow Plan Symbols Sub-Committee
  - Pneumatic Control Circuit Pressure Tests Sub-Committee
  - Outside Instrument Protective Cabinets Sub-Committee
  - Support and Protection of Instrument Piping Sub-Committee
  - Mercury Handling Sub-Committee
  - Instrumentation for Hazardous Locations Sub-Committee
  - Instrumentation for Corrosive Services Sub-Committee
  - Recommended Practices for Head Meter Installation, Calibration and Piping Sub-Committee
  - Plant Type Analytical Systems Sub-Committee
  - Instrument Signals and Alarms Sub-Committee
  - Mounting Dimensions for External Displacement Level Instruments Sub-Committee

The organization leaves President McMahon with the general over-all responsibility and also two committees: the Society Structure and Planning Committee and the Nominating Committee.

First Vice President Porter Hart must be ready to take over the President's responsibility in his absence and also has the supervision of any special committees. At present there are only two special committees, the Special Committee for Abstracting Service, and the Special Manpower Classification Committee.

George Feeley has the very difficult job to fill Hugh Ferguson's shoes. For this he has had the best preparation, having been chairman of the Finance Committee for two years. It was under George's direction that the present Society Budget System was installed.

The Executive Secretary only has to take care of a lot of miscellaneous jobs. He would be very glad to have you drop-in at the National Office some time and a guided tour will give you some idea of a few of them.

In the next issue of the *ISA Journal* the members constituting the committees will be given.

In closing, I wish you a Happy New Year.

R. Rimbach

Foreign Companies Show Interest in 1951 Exhibit

The following foreign companies and countries have expressed interest in exhibiting at the Sixth National Instrument Exhibit at Houston, September 10 to 14, 1951.

Austria:	C. Reichert Optische Werke (Optical Instruments)
England:	British Embassy Elliott Brothers Ltd.
France:	Comite Franc-Dollar (Committee for the Development of French Exports)
Germany:	Elster & Co. Aktiengesellschaft (Gas Meters) German-American Trade Promotion Office H. Maihak Aktiengesellschaft (Gas Analyzers and Engine Indicators) Arthur Metzke (Electrical Instruments) Siemens & Halske Aktiengesellschaft (Electrical Instruments) Verband der Deutschen Mechanischen und Optischen Industrie E. V. (Instrument Trade Association) Carl Zeiss, Inc. (Optical Instruments)
Israel:	Goldberg Instruments Ltd.
Italy:	Apparecchi Branca Soc. per Az. Emanuele Mascherpa
Sweden:	Royal Consulate of Sweden

1950 Show Attendance

Below are to be found several tables containing some rather interesting information derived from the analysis of the attendance at the Buffalo Conference and Exhibit. If you have attended any of the ISA Shows you certainly remember the registration card which you filled out before being admitted to the exhibit hall or the conference rooms,—it is from the cards completed in Buffalo that the following information has been taken.

GEOGRAPHICAL BREAKDOWN

NEW ENGLAND 269	
Connecticut	86
Maine	2
Massachusetts	165
New Hampshire	1
Rhode Island	15

MIDDLE ATLANTIC 3668	
New Jersey	132
New York	3103
Pennsylvania	433

SOUTH ATLANTIC 172	
Delaware	28
Dist. Columbia	38
Florida	2
Georgia	6
Maryland	49
N. Carolina	3
Virginia	25
West Virginia	21

E. NORTH CENTRAL 619	
Illinois	178
Indiana	41
Michigan	119
Ohio	270
Wisconsin	11

E. SOUTH CENTRAL 45	
Alabama	5
Kentucky	11
Mississippi	1
Tennessee	28

W. NORTH CENTRAL 44	
Iowa	14
Minnesota	12
Missouri	28

W. SOUTH CENTRAL 66	
Louisiana	9
Oklahoma	18
Texas	39

MOUNTAIN 15	
Colorado	4
New Mexico	11

PACIFIC 53	
California	47
Oregon	1
Washington	5

FOREIGN 31	
Arabia	1
Australia	1
England	4
France	1
Germany	1
Holland	2
India	1
Indonesia	2
Japan	1
Mexico	3
Netherlands	9
South America	3
Spain	1
Sweden	1

GRAND TOTAL 5206	
U.S.A.	4951
Canada	224
Foreign	31

VISITORS WHO ATTENDED PREVIOUS ISA EXHIBITS

Chicago (1947)	80
Philadelphia (1948)	286
St. Louis (1949)	141
Both Chicago and Philadelphia	101
Both Philadelphia and St. Louis	135
Both Chicago and St. Louis	51
Chicago, Philadelphia and St. Louis	310

NUMBER OF MEMBERS OF COOPERATING SOCIETIES

American Institute of Physics	169
American Society of Mechanical Engineers	383
American Institute of Electrical Engineers	353
Institute of Radio Engineers	214
Instrument Society of America	870

275 men volunteered the information that they held memberships in Technical Societies other than those listed above.

VISITORS USE OF HOTEL ACCOMMODATIONS

306	Stayed 1 night
333	Stayed 2 nights
220	Stayed 3 nights
188	Stayed 4 nights
458	Stayed 5 or more nights

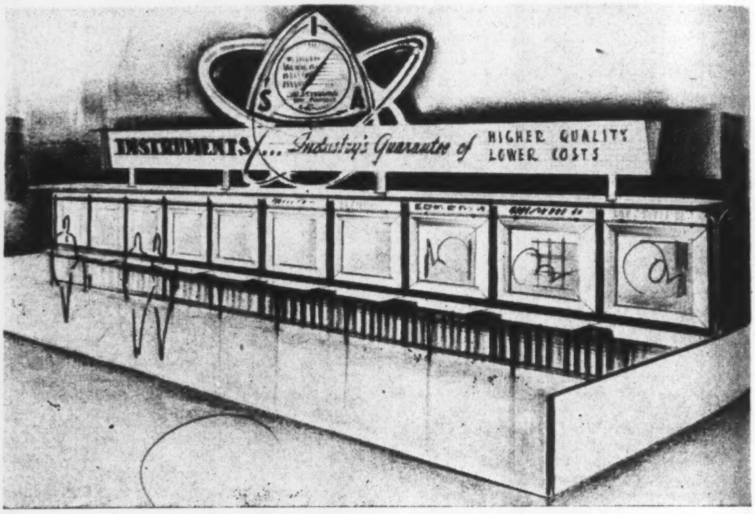
287 men listed a Buffalo Hotel as an address but did not specify the number of nights they would stay.

A New Feature at the Houston Exhibit

At the end of last month the Exhibit Space Reservation Forms for the Sixth National Instrument Exhibit, to be held in the Sam Houston Coliseum in Houston, Texas during September 10-14, 1951, were mailed out to the exhibitors who took part in the St. Louis and in the Buffalo exhibits. These exhibitors have been given a 30-day option on space at the Houston Exhibit. At the end of this option period, the ISA Allocations Committee under the chairmanship of Lester C. Books (Houston Section), will meet to allocate the space.

A floor plan of the Houston Exhibit is reproduced herewith, and it can be seen that there is a central area on the plan marked "User Exhibits". This central area will be treated as shown in the accompanying sketch. A head-piece will have an enlarged ISA emblem revolving in a flood light in this central dominating area in the Exhibit Hall. In this area, ten panel units 5 ft. by 8 ft. will be placed back to back with another ten units. The head piece will provide sufficient light to illuminate the panels. Only 20 units will be available. This instrument users' exhibit area will be arranged to accomodate display panels which are 5 ft. wide by 8 ft. high and which can run to a maximum depth of 12 inches. Each unit will show the name of the company displaying the panel and will have a shelf for literature on the products shown. The society will provide chairs in this area for visitors and for the men manning the displays.

This panel space can be obtained singly or in multiples of 5 ft. by manufacturers who are users of instruments at a rental cost of $200 per unit, the actual panel to be furnished by the user company. This cost is all inclusive; there will be no charges for an electrical connection, for moving cases in and out, etc., etc. If the company of an ISA member is interested in taking advantage of this rather unusual opportunity, arrangements can be made through the National Office.


I S A
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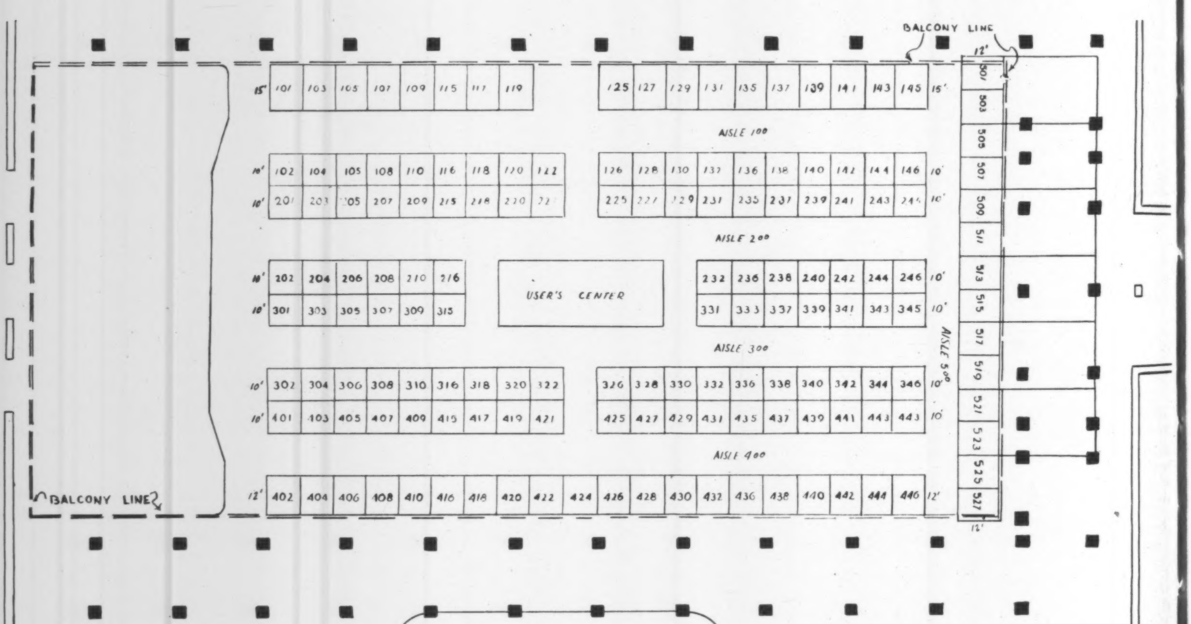
Artist's sketch of proposed "User's Center" area.


BALCONY LINE
15' 101 103 105 107 109 115 117 119
125 127 129 131 135 137 139 141 143 145 15'
AISLE 100
10' 102 104 105 108 110 116 118 120 122
10' 201 203 205 207 209 215 218 220 22
126 128 130 132 136 138 140 142 144 146 10'
225 227 229 231 235 237 239 241 243 24 10'
AISLE 200
10' 202 204 206 208 210 216
10' 301 303 305 307 309 315
USER'S CENTER
232 236 238 240 242 244 246 10'
331 333 337 339 341 343 345 10'
AISLE 300
10' 302 304 306 308 310 316 318 320 322
10' 401 403 405 407 409 415 417 419 421
326 328 330 332 336 338 340 342 344 346 10'
425 427 429 431 435 437 439 441 443 443 10'
AISLE 400
12' 402 404 406 408 410 416 418 420 422 424 426 428 430 432 436 438 440 442 444 446 12'
AISLE 500
12'
501 503 505 507 509 511 513 515 517 519 521 523 525 527
12'
BALCONY LINE
REGISTRATION LOBBY

FLOOR PLAN OF THE HOUSTON EXHIBIT

ISA EMPLOYMENT SERVICE

Forward your letter to INSTRUMENT SOCIETY OF AMERICA, 921 Ridge Ave., Pittsburgh 12, Pa.

ENGINEERS (RESEARCH AND DEVELOPMENT). For missile instrumentation, electronics, radar, physical analysis, and precision mechanical design. Openings for specialists in any one field or those having extensive general experience in one or more fields. Give complete resume of age, background, education, experience in first letter. Location California. Box 418.

INSTRUMENT DESIGN ENGINEER. Leadman capable directing research projects in field of precision electromechanical instruments and servomechanisms. Attractive salary for right man. Permanent opening in established company. Location near Philadelphia, Pa. Box 419.

INSTRUMENT ENGINEER. 2 to 8 years experience in design of electronic circuits and associated equipment for measuring pressures, temperatures, displacements, etc. E. E. or M. E. degree preferred. Permanent position with growing research laboratory. Salary open. Location Texas. Box 420.

INSTRUMENT ENGINEERS. By large chemical manufacturer for work in various phases of instrumentation including design, installation of control equipment for new and revamped facilities, general application, engineering and training of personnel. Must have degree and at least four or five years experience in industrial instrument field. Experience in chemical processing, petroleum, textile or instrument manufacturing industries preferred. Give background, experience, and education in first letter. Age 24-40. Salary $6500.00 and up depending on qualifications. Location Delaware. Box 421.

INSTRUMENT ENGINEER. Under 45 years of age. B.S. in Elect., Mech., or Chem. Engrg. Five to ten years in instrument research and/or development. Must have broad and thorough knowledge of instrument theory and application. Should have some knowledge of chemical equipment and its operation. To provide engineering consultation on instruments and instrument problems to plant and technical personnel. Location Delaware. Box 422.

INSTRUMENTATION ENGINEER. B. S. in Chem. Engrg. Age 28 to 35. Five or more years of progressively difficult experience in chemical process design or in instrument design. Sound understanding of process design. Work under supervision of Senior Instrument Engineer to perform necessary engineering for projects, to assist in the preparation of basic data from which will prepare a scope of work, make all engineering calculations, prepare specifications, select all equipment and supervise instrument design. Location Delaware. Box 423.

INSTRUMENTATION ENGINEER (CONSTRUCTION). B. S. in E. E. or M. E. Age 26 to 35. Must have practical instrument experience. Should have some experience in directing the work of an instrument group. To supervise and coordinate instrument installation at a construction site; required to organize and direct a group of instrument mechanics and to coordinate installation of instruments, analyze drawings and specifications and interpret requirements to Area Engineers, Craft Superintendents and Mechanics; calibrating testing, responsible for take-off instrument materials. Location Delaware. Box 424.

INSTRUMENT ENGINEER (OVERSEAS). Graduate preferably mechanical engineering, minimum three years experience in gas measurement, testing, and instrument work by large oil company. Detailed requirement of position sent on written request. Salary about $475.00 per month plus $75.00 per month single status Variable plus annual Utilidades payments equivalent at present to approx. 16 2/3 percent of total salary and Variable. Married men authorized to take family about 6 months after employment and Variable increased to $150.00 per month. Location Eastern Venezuela. Box 425.

INSTRUMENT ENGINEERS AND MECHANICS. Chemical Company in process of placing ethyl alcohol plant in production desires to locate several competent instrument men. Location Oregon. Box 426.

INSTRUMENT SALESMAN. Manufacturer of automatic controllers, regulators, control valves requires company employed salesman for Philadelphia, Pa. area. Box 427.

INSTRUMENT MECHANIC. Must have at least five years experience and be well grounded in process control instruments for chemical plant. Should have all around first class experience in installation, operation and maintenance. Give details of experience and rate expected in first letter. Location Texas. Box 428.

INSTRUMENT MECHANICS. For National Lead Co., Titanium Div. Must have 5 years of industrial experience in flow meters, potentiometers, gages, thermometers and automatic controls. Forty hour week, $1.87 per hour. Location New Jersey. Box 429.

INSTRUMENT ENGINEER. Graduate engineer preferred. Must have at least five years of well rounded experience in industrial instrumentation including selection, installation and maintenance for chemical manufacturer. Location New Jersey. Box 430.

INSTRUMENT MECHANICS. For repair and maintenance of pneumatic instruments used in synthetic rubber industry. Location Kentucky. Box 431.

Employment and the Instrument Industry

Since the inception of the Employment Service of the Society, our employment files had held until recently, a considerable number of employment application cards of well qualified men who were available for employment. The high point in the number of men available was reached in the Summer and Fall of 1949. The majority of these men were employed but dissatisfied but there were also a number unemployed owing to economic measures adopted by some industries.

To assist these men, the Employment Committee in addition to operating the Employment Service, endeavored to compile a National directory of employers of instrument men. The purpose of the directory was to inform the employers of the facilities of the Employment Service, the availability of qualified instrument men and to invite advice of openings as they occurred. During the last half of 1949 better than three hundred prospective employers were contacted and advised of our purpose. A number of ackowledgements were received and some few openings were developed. These openings along with those which came to our attention from other sources were quickly filled from our files and through the large application response from publishing the openings in the Journal of the ISA. However, even with these efforts the end of 1949 found approximately one hundred men (engineers and mechanics) registered with the Employment Service as being available for employment.

Early in 1950 positions began to open up. The Employment Service was able to advise applicants of openings at a gradually accelerated rate. Other applicants found their own new connections and requested their application cards to be removed from our files. Still others ignored our advice of openings and their cards were removed from the files as it was believed that they were now agreeably employed and no longer needed our effort.

This trend continued through the Spring and Summer of 1950 until by the time of the Fifth National Instrument Conference and Exhibit in September 1950, our files had reached an all time low of men available and an all time high of open positions. This was well illustrated by the Employment Register conducted during the Conference and Exhibit. Seventy-five positions were posted and forty-two prospective employers visited the Register to obtain instrument men. While ninety applicants filed for the open positions, reports indicate that little actual employment was accomplished. It seems the majority of the applicants had employment and were only looking for better conditions than either their employers or the prospective employers had to offer.

The seventy-five open positions posted at the Register were published in the October 1950 issue of the Journal of the ISA to give those who did not attend the Conference and Exhibit an opportunity to bid on the job or jobs of their choice. Only thirty-two individuals sent in applications for only thirty of the seventy-five openings.

Certainly this condition indicates that the instrument employment pendulum has passed the bottom of its swing and is now climbing toward the peak of many openings and no applicants. For the first time the activities of the Employment Committee are being directed to seeking applicants for needful employers. However, there are extremely few experienced men available today, and yet the requests for men from the prospective employers all carry the requirement that the men must have five to ten or more years of working experience. Under present conditions the time will soon come when *no experienced men are available.*

Such a condition can result in the very undesirable practice of the pirating of men from other plants of like industry. It is to be hoped that this probability will be recognized before harm may be done; that the Society, the instrument manufacturers and the instrument user industries will immediately devise plans for training men; and that prospective employers will not be adverse to accepting theoretically trained men with little or no actual experience.

—C. F. GOLDCAMP, *Chairman*
National Employment Committee

Allen Hill, Jr.

The Niagara Frontier Section announces with deep regret the death, on July 6, 1950, of Mr. Allen Hill Jr., of Sanborn, N. Y. Mr. Hill had been a member of the Section since September of 1947.

Frederick Carl

It is with deep regret that the Washington D. C. Section announces the death on July 16, 1950 of one of its Charter members, Frederick Carl, Washington, D. C. Mr. Carl had been a member of the Section since January 1946.

Railway Signaling

By G. W. BAUGHMAN *

Abstract. The intent of the paper is to treat the main devices of railway signaling as instruments and to show the various principles of instrumentation that are used in railway signaling. The basic principles of the track circuit are explained, this being a fundamental principle that is used in all railway signaling systems. There is a discussion of the coding of the track circuit in accord with the traffic conditions in advance. It is explained how the coded track circuit may be used in the system of cab signaling, that is, the displaying of the signal indication in the cab before the engineman. The basic principles of Centralized Traffic Control are discussed. It is shown how switches and signals may be controlled safely from a control point which may be several hundred miles from the actual switches and signals being controlled. It is this system which was used to such good advantage in increasing the track capacity of the single track railroads during World War II.

The object of this presentation is to give some of the basic principles of railway signaling and then to show the way these principles are employed in two of the main systems of railway signaling that are of outstanding interest at the present time. An attempt has been made to select the material in such a way as to emphasize the principles of instrumentation used in such systems.

The first important function of railway signaling is to detect the presence of a train automatically and with the utmost in reliability. The "track circuit" which was first used in its elementary form in 1872 is now universally accepted for the purpose of detecting the presence of a train, checking that the rails are intact and that any switches which may be included within the circuit are in proper alignment.

Let us now refer to the elementary diagram of the track circuit, shown in a style that is symbolic of the time of its invention. Electrically the circuit is a very simple one consisting of a source of energy at one end of a section of track and a receiving device in the form of a relay at the opposite end. The rails serve as electrical conductors in the track circuit. Insulated joints are placed in the rails at each end of the circuit thus dividing the track into a series of electrically separate sections. The detection of a train occupying the track circuit is obtained by the release of the track relay due to current being shunted from it by the wheels and axles of the train. There are several very important and basic principles shown in this circuit to which I should like to call your attention. The closed circuit principle is employed and by this we mean that a relay is required to be energized steadily in order that the signal may display a proceed aspect. If there should be a fault develop such as the loss of the source of energy, an open or short circuit in the leads from the source of energy to the track or from the track to the relay, the track relay would release and place the signal at stop. In the event of a rail being broken or a section of rail removed, the track relay will be de-energized and this failure will be on the side of safety. If a switch or turn-out should not be in proper alignment for the safe passage of a train, a shunt is placed on the track circuit by a device controlled by the points of the switch known as a "circuit controller". In the design of railway signal systems we make use of the closed circuit principle and the goal for the design of circuits and apparatus is that the failures be reduced to a minimum, but if any failure should develop it should be on the side of safety.

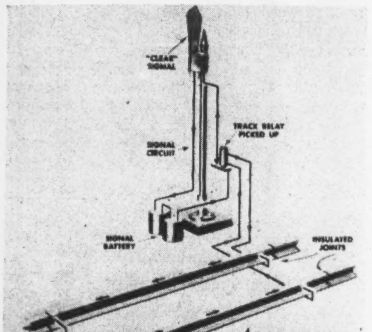


Fig. 1. Current flows through rails of entire section from battery to relay.

The length of track circuits used in modern signal systems is frequently in the general order of 10,000 ft. The actual length that is used depends upon a number of details, including the function of the particular track circuit, the actual leakage that is encountered between the rails in wet weather, and the type of bonding that is used for establishing electrical connections from one rail to the next. In order to obtain the best over-all operation and reliability of long track circuits the track relay should be matched with the characteristic impedance of the track circuit. In the most usual instance for long track circuits the relay has a resistance in the order of 0.10 to 0.50 ohm. A limiting device such as a resistor is connected in series with the source of energy so the train will not short circuit the source. The value of this resistor also has a bearing on the shunting sensitivity and broken rail protection afforded by the track circuit.

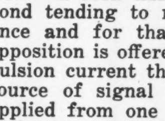
We make use of the same general techniques for calculation of track circuits as are used for transmission line calculations. In the direct current track circuit we have the resistance of the rails with distributed leakage between them. The usual value of minimum resistance between rails in wet weather is 3 ohms per 1000 ft. The hyperbolic functions are found to be the most convenient way to arrive at a prompt determination of the track circuit characteristics, taking these factors into account.

You may be thinking in terms of the difficulties that would be involved in the event of signaling a railroad where electric propulsion is used. In this instance the rails would serve as a return patch for the propulsion current and there would, therefore, be serious objection to the use of insulated joints as shown in Fig. 1.

Let us now refer to Fig. 2 which shows the method usually employed in electrified territory. The source of energy in this instance is alternating current and if the propulsion is alternating current the frequency for signaling is selected different from that of the propulsion system. A reactor is connected from one rail to the other at each end of each track circuit. The mid-points of the reactors on each side of a pair of insulated joints are connected together. These reactors, known in railway signaling as impedance bonds, must have a conductivity suitable to carry the propulsion current. You will observe that the propulsion current has approximately the same value in each half of each impedance bond tending to neutralize the reactance and for that reason very little opposition is offered to the flow of propulsion current through the bond. The source of signal energy, however, is applied from one rail to the other in such a way that the voltage across the impedance bond due to the source of signaling energy is across the entire bond. The bond, therefore, offers an impedance to the signaling frequency and permits the track circuit to function in very much the same way as if the impedance bonds were not present. Usual values of these impedance bonds are in the order of 1 to 4 ohms at the signaling frequency.

Track relays for steady energy a.c. track circuits employ the induction motor principle. The vane type of track relay has an aluminum vane and has

THE AUTHOR



Graduated from Ohio State University in 1920, Mr. Baughman received the Professional Electrical Engineering degree in 1924. He was employed by the Bell Telephone System in New York City from 1920 to 1923, when he joined the Union Switch and Signal Company. He has done considerable work on automatic cab signals and train control, subway signalling, braking systems for high-speed trains, and centralized traffic control systems. He was appointed Assistant Chief Engineer in charge of Electronics in 1944, Chief Engineer in 1945, and Assistant Vice President, Engineering, in 1950.

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* Union Switch & Signal Co., Swissvale, Pa.

NOTE: Presented before the Fifth Annual Convention of the Instrument Society of America, at Buffalo, N. Y., Sept. 12-18, 1950.

Statements and opinions expressed in these articles are those of the author and not necessarily those of the Society.

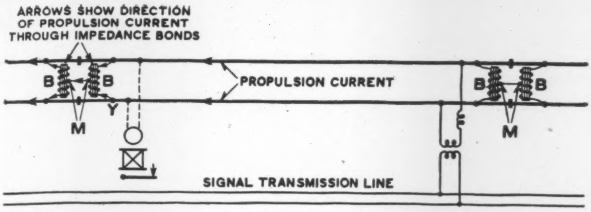
ARROWS SHOW DIRECTION OF PROPULSION CURRENT THROUGH IMPEDANCE BONDS
B
B
PROPULSION CURRENT
B
B
M
Y
M
SIGNAL TRANSMISSION LINE

Fig. 2.

many characteristics similar to the vane type Watt hour meter. A Copper Cup rotor is used in the motor type relay, the Stator being wound similar to a two phase induction motor. The Centrifugal type of track relay makes use of the principle that the no load speed of an induction motor is approximately proportional to the frequency. In this manner the centrifugal relay is selectively responsive to the signaling frequency and is not affected unsafely by alternating current propulsion, the signaling frequency always being selected to have a value greater than that of the propulsion current.

Communication of Information From the Equipment That Detects the Presence of the Train to the Signals to Control Oncoming Traffic

In the early days the method for transmitting information to the various signals was by transmitting energy over line wires that were carried on poles parallel to the track. Energy would be applied to the line wires at one signal location for the operation of a line relay at the next signal. By the use of various circuits dependent upon the positions of the various line and track relays there was considerable latitude for arranging signal systems to perform functions consistent with the local conditions encountered. The signal directly in the rear of a train is placed in the stop position because of the release of the track relay. The next signal is placed in the caution position and the next one in the clear position. This assumes the most simple form of signaling and the indications are usually given by light signals with colors corresponding to the usual ones encountered in highway traffic signals. The minimum spacing between the stop signal and the caution signal is selected so that it will afford a satisfactory margin for the stopping of the train if the brakes are applied "in service" as the locomotive passes the caution signal. Such conditions as speed of the train, grade, and curvature are taken into account in the spacing of the signals.

The more modern method for transmitting information from one signal to the next is to use the rails as the electrical conductors instead of the line wire. The rails thus serve as conductors in the circuit which detects the presence of the train and also transmit the information from one signal to the next. A simplified schematic of the modern arrangement known as "coded track circuit control" is shown in Fig. 3. The general principle of the scheme consists of interrupting the current supplied to the track at a rate selected in accord with traffic conditions in advance. When block A is occupied the track circuit energy applied to block B is interrupted at 75 times per minute. When block A is unoccupied the energy applied to block B is interrupted at 180 times per minute. The interruption of the track circuit energy is accomplished over contacts of a device known as a code transmitter. Usually there is one code transmitter for each rate of interruption.

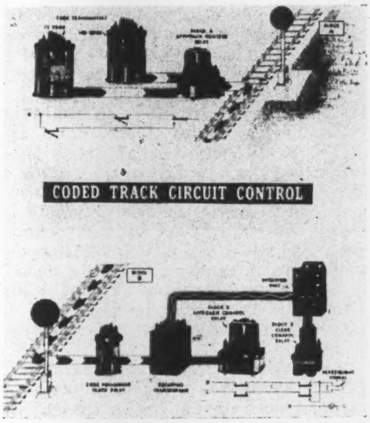

Fig. 3.

At the other end of the circuit is apparatus that will distinguish between these two rates of interruption and will detect whether the particular circuit is occupied. The basic principle which is used to select between these rates of interruption is to derive an alternating current having the same frequency as the particular rate of interruption and then make the determination by use of electrically resonant circuits.

The "code following" relay is connected directly to the rails of the circuit so the armature of this relay responds in accord with the interrupting rate in much the same way that a telegraph relay responds to telegraph code. A direct current circuit is controlled over the contacts of the code following track relay in such a way that pulses of d.c. energy are applied to the primary of the decoding transformer. An alternating voltage is developed at the secondary of the decoding transformer in accord with the rate of interruption of the track circuit energy. If the rate of interruption is 180 per minute the alternating voltages at the secondary of the decoding transformer will be 180 cycles per minute or 3 cycles per second. This energy is delivered to a resonant unit consisting of a reactor and capacitor in series resonance at this very low frequency of 3 cps. A low percentage auto-tap is taken from the reactor and the alternating voltage is applied to a copper-oxide rectifier where it is changed to direct current energy for the picking up of the clear control relay. If the rate of interruption of the track circuit energy had been 75 per minute, thus indicating that block A was occupied, the frequency at the secondary of the decoding transformer would have been 75 per minutes or 1¼ cps., which would be too low for the picking up of the clear control relay. The caution control relay, however, would pick up on this frequency and thus display the caution signal. If a train were between the two signals shown in Fig. 3, the armature of the code following track relay would be stationary and in its released position so that no alternating current would be present in the secondary of the decoding transformer. Under this condition both the clear and caution relays would be released and the signal controlling entrance to block B would be in the stop position.

In the signaling on railroads where the traffic is relatively dense it is frequently desirable to include another signal indication. This is provided in the coded track circuit system by the use of an additional interrupting rate which is 120 per minute. Fig. 4 shows a schematic diagram of a decoding circuit showing resonant devices for the 120 and 180 per minute rates of interruption, together with an unturned relay that will pick up on any one of the three standard frequencies.

Your particular attention is called to the resonant qualities of the decoding units at these very low frequencies. There is extremely good selectivity existing between the frequencies of 1¼, 2, and 3 cps. This general principle has proved to be an extremely safe one and is applied to a large extent in various railway signal systems. Working at the proper position on the magnetization curve and the current characteristics of the Copper oxide rectifier are factors which contribute to the selectivity that is realized.

Coded track circuits are sometimes referred to as "Universal" track circuits because they may be applied to either electrified or non-electrified propulsion railroads.

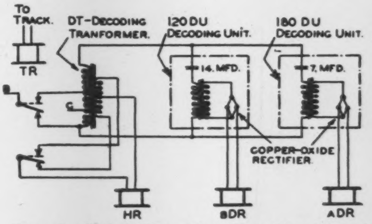

Fig. 4. Coded Wayside—Decoding Circuit —Using Mechanical Rectification to Operate HR Relay.

Displaying the Indication on the Locomotive in Front of the Enginemen — Cab Signaling

We shall now describe the general method that is used when it is desired to display the indication in the cab so the engine crew is given information in regard to the traffic conditions in advance even though they may not be able to see the wayside signal clearly. Difficulty in seeing the wayside signal may be due to snow, rain, fog, or smoke. Let us assume the impulses are delivered to the track having the same rates of interruption and the same method of control as shown in Fig. 3. If the supply of energy to the track circuit is alternating current instead of direct current, we then have the arrangement of wayside apparatus that will permit the signals to be displayed in the cab.

The equipment carried on the locomotive is indicated in Fig. 5. The rails are shown in the lower part of the diagram and it is assumed that alternating current interrupted at a rate in accord with the traffic conditions in advance is flowing at a given instant down one rail and back the other. The receiver coils shown above the rails are mounted ahead of the front wheels of the locomotive. Each receiver consists of a laminated bar around which is wound a coil with a relatively large number of turns. The two receiver coils are connected series aiding for current flowing down one rail and back the other. You will observe that the rails act as the primary of a current transformer and the receiver coils as the secondary. The voltage from the secondary coils is delivered to an amplifier through a selective filter. The output of the amplifier is connected to a "code following" relay of the general type as described in connection with coded wayside signals. Direct current energy over the contacts of this relay is delivered to the primary of the decoding transformer. Thus alternating current is derived on board the locomotive with a frequency equal to the rate at which the track current is being interrupted. The decoding, by means of electrically resonant circuits selectively responsive to the low frequencies, employs the same principles that were described in connection with the coded wayside signal system. The indication displayed on the cab signal is in accord with the particular decoding relay that is in its picked-up position. The electrical circuits are so arranged that in the event of a change at any time to a more restrictive indication the engine crew is warned by an audible alarm in the form of a continuous whistle which blows until an acknowledgment is made. This acknowledgment consists of the movement of a manually operated switch from its normal to its reverse position followed by its return to normal.

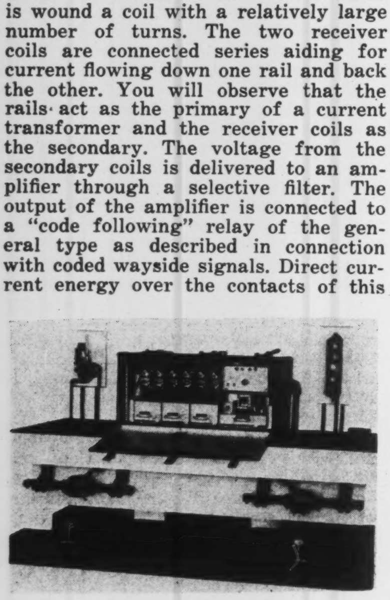

Fig. 5.

Apparatus is available so that the brakes of the locomotive will be applied automatically in the event of a failure to acknowledge a change to a more restrictive indication. Apparatus is also available to control contacts in accord with the speed of the locomotives. Electrical circuits involving the speed control contacts and the decoding relays are available so that a definite speed limit may be assigned for each of the indications of the cab signal.

There are at present approximately 5,540 locomotives in this country equipped with apparatus so that a cab signal is displayed in front of the engine crew. There are approximately 9,580 miles of track equipped so that cab signal indications will be received by the equipped locomotives passing over the track.

Fig. 6 shows a typical view of the appearance of the cab of a Diesel locomotive showing the position of the cab signal which in this instance is indicating clear. Incidentally, the loudspeaker shown adjacent to the cab indicator is one element of the train communication system which is becoming increasingly important on the railroads.

Centralized Traffic Control

Our discussion thus far has dealt with railway signaling mainly from the standpoint of providing safety for the operation of trains. In addition to providing safety, railway signaling can also expedite traffic. The outstanding system that has brought about such an increase in the amount of traffic that can be handled over a given set of track conditions is known generally as Centralized Traffic Control. It is this system which had so much to do with the increasing of the track capacity on the single track lines of this country when they were being so overloaded just previous to and during the past World War. The points of greatest traffic congestion occurred where the single track lines went over the mountain grades. It is evident that the trains would have to move slower over these sections, be broken into two or more trains, or be aided by helper locomotives. Thus the Government authorized Centralized Traffic Control installations at these points of maximum congestion and the installations were placed in service just as quickly as was possible. These installations had the effect of expediting the traffic on the previously congested sections to the extent that the traffic delivered from the flat territory was handled readily.

Before explaining how this system operates it is desirable to call your attention to the previous method of operation so you can obtain a better appreciation of the benefits derived by the use of Centralized Traffic Control. Let us assume a division of single track railroad which is under the direction of a dispatcher who is usually located at one end of the Division. A modern dispatcher's office is shown in Fig. 7. The two tables at the front show dispatchers operating in accord with the previous standard method, while the machine at the rear of the room shows a dispatcher in front of a Centralized Traffic Control machine. In the dispatching of trains by the "train order" method the dispatcher has the responsibility for transmitting messages to operators located along the railroad for the operation of the trains. The operators receive these messages and they in turn have the responsibility for delivering the messages to the proper train crews. It is understood that if the entire territory is protected by a wayside signal system safety is afforded the operation of the trains even though the dispatcher should issue an incorrect order. It is necessary, however, for the dispatcher to make his plans definitely and send out the corresponding orders so that each train crew knows where another train is to be met and which train is to take the

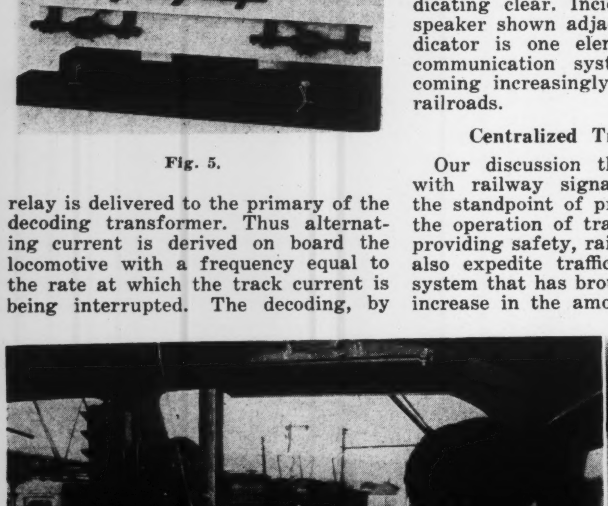

Fig. 6.

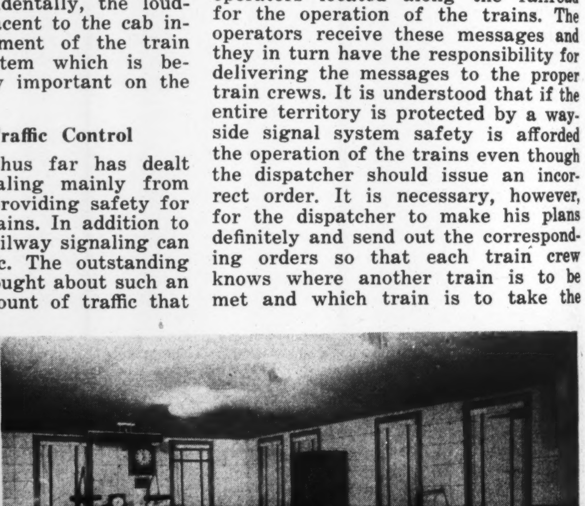

Fig. 7.

siding. This method of operation has been developed through the years and in general performs satisfactorily as long as the traffic is not too heavy and when the whole program moves along very much as anticipated by the dispatcher. As traffic increases the work of the dispatcher naturally increases and it was this condition, combined with the irregularities in train schedules which made the work of the dispatcher a most difficult one in the period referred to. In many instances there were so many trains to handle that it was necessary to put some of the trains on sidings and leave them there for a matter of hours in order that the more important ones could be moved.

A study made by Carey P. McCord, M.D. and presented in the October, 1948 issue of "Industrial Medicine" gives an excellent picture of the work of a dispatcher with particular reference to the physical toil on the dispatcher of a busy single track railroad.

Let us now indicate how trains are operated on the same kind of railroad by means of the Centralized Traffic Control system. The entire territory being governed by this system is equipped with an automatic signal system so that all of the basic safety is applied in accord with the general principles indicated in the early part of this paper. The head block signals, those at the end of the passing tracks for the purpose of establishing direction will all be normally at stop. There are two conditions that must be met before a head block signal will clear, establishing the direction of traffic. The first is that the man at the machine must operate the particular lever and the corresponding information be transmitted from the machine to the wayside signal system indicating that the operator wishes the particular signal to be cleared. The second is that the traffic conditions are such that it is safe for the signal to clear. It is essential to realize that there is a check made in the field that it is safe for the signal to clear before the signal will actually display the clear aspect. You will observe that this relieves the operator of all responsibility as far as safety of operation is concerned and leaves his mind free to manipulate the levers to handle the traffic most efficiently.

A close-up view of a Centralized Traffic Control machine is shown in Fig. 8. Along the top of the machine is a diagram of the track over which the man has control. The lights on this diagram indicate the positions of the trains in the territory. The levers located directly below the track diagram are associated with the switches and signals, there being identifying numbers relating the levers to the track diagram. Fig. 9 shows a man at work at one of the largest Centralized Traffic Control machines now in service.

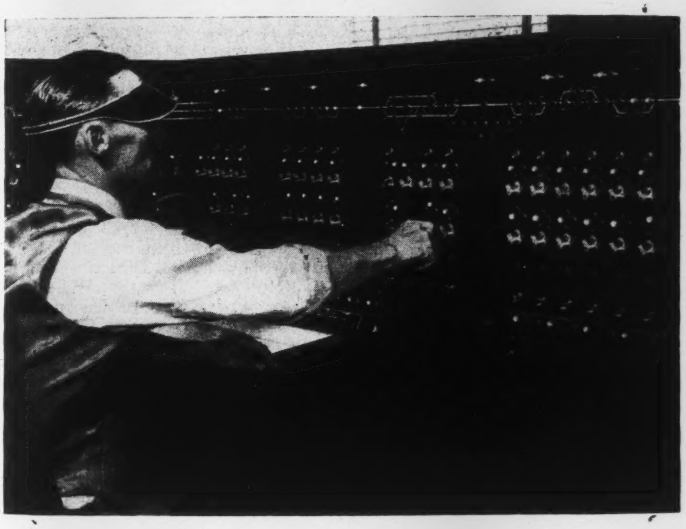

Fig. 8.

It is the usual practice to have a power-operated switch at each end of each passing track so the switches may be positioned in response to the movement of the proper lever by the operator. The control of the switch is similar to that for a signal in that the switch cannot be moved by the operator unless the traffic conditions are such that it is safe for the switch to be moved.

With this brief description of the Centralized Traffic Control machine, let us now indicate how the operator handles the traffic with this system. There are no orders transmitted for normal operation. The only orders the train crews have are that they shall operate in accord with the signal indications. As described previously, the signal indications are under control of the operator, so it may be said that the operator conveys his messages to the train crews by the positioning of the wayside signals. Word is received by the operator over a telephone line that a train is expected to enter his territory at a given time. The operator then positions the signals and switches for the entrance of that train into the territory. The operator is kept advised of the progress of the train by the lights on the track model. In this manner trains may be admitted at either end of the single track territory. The operator who is very familiar with the railroad, progresses the trains by clearing one or more signals in advance, studies the movements of the trains and determines the particular sidings at which meets are to be made. It is not necessary for him to make this decision very long in advance of the actual meeting time, and for this reason he is able to select the particular siding at which the trains may meet most efficiently and with the very minimum in the way of loss of time. The train crews are informed by the signal indication whether their train will take the siding or stay on the main track. The switch, of course, will be in its proper position previous to the arrival of the train so it will not be necessary for any member of the train crew to get off and throw the switch for the one train to enter the siding as was necessary with the previous method. Likewise, no one has to drop off the rear of the train to "line up" the switch after the rear of the train has passed the switch. In many instances these meets can be made without either of the trains stopping. These are referred to commonly as "non-stop meets'" Through experience the train crews realize that a meet is in progress and they usually adjust their speeds during the meet so that it will be accomplished with the minimum loss of time.

In addition to permitting this general type of operation, the system also provides a record for the movement of all trains. This record is provided on a chart known as a "train graph" which is advanced by a synchronous motor drive so the chart advances accurately in proportion to time. The train graph

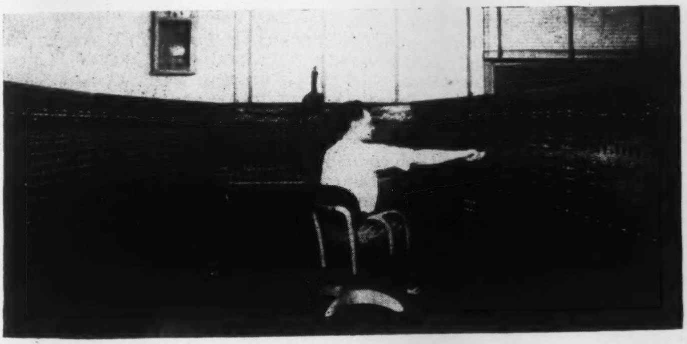

Fig. 9.

thus provides a record of all train movements and, therefore, it is not necessary for the man to keep the detailed record on the train sheet which previously required so much time and effort on the part of the dispatcher.

Fig. 9 shows a man at work at one of the largest Centralized Traffic Control machines in service at the present time.

Some interesting empirical data that have been derived from a large amount of practical experience with the Centralized Traffic Control are: (1.) The average saving in time for freight train operation is one minute per mile traveled. (2.) The usual single track railroad equipped with Centralized Control will handle 75 per cent of the traffic that can be handled on a double track railroad operated by present conventional methods, not employing Centralized Traffic Control.

(This does not mean that Centralized Traffic Control is limited to single track railroads. It has been applied very effectively to double track railroads particularly in the handling of commuter traffic to some large cities to take care of the heavy in-bound traffic in the morning and the heavy outbound traffic in the afternoon.)

Electrical Principles Used in Centralized Traffic Control

Let us now explain the main electrical principles that are used in transmitting the information from the office to the field for the control of the switches and signals. When the operator positions one or more levers and operates a push-button a code is generated automatically by relay operations and is applied to a two-wire line circuit. The code consists of a series of long and short impulses, the first part of which determines the particular field station and the last part contains the information in regard to the desired position of the switch and signal at the selected location. Fig. 10 is a simplified schematic diagram of the line circuit showing the office and only one field station. It is understood that the actual installation would have additional field stations connected in exactly the same manner as the one shown. In the transmission of the control code the source of line battery is interrupted by contacts of the transmitting relay indicated as T. The line relay at each of the field locations picks up and releases in accord with the position of the transmitting contacts at the office. The contacts of each field line relay apply pulses to the corresponding field line coding unit, which is capable of distinguishing when the code is for that particular location. The same unit is capable of detecting the desired position for the switch, signal, or any other function at the location. The selecting of the proper field station by a control code may be compared in general to the dialing of a particular station by means of the usual telephone dial. With this system, however, all codes are generated automatically by relay operations and are not dependent upon the manipulation of a dial. Particular attention is directed to the fact that the line wires are continuous and that the main circuit is not opened at any location except at the office. Thus, in the event of a fault in the form of a broken wire the system may function normally out as far as the break.

The problem of conveying information from the field to the office required much more study than that of conveying the information on controls. It was, of course, desired that there be only one line battery so it was necessary to develop a means for transmitting the pulses from any field station to the office with the source of line battery being located at the office. The basic principle is illustrated in Fig. 10. When a train occupies a particular circuit at the field location, or when any function at that location changes position, it is the duty of the field station to transmit the new information to the office. This is accomplished by the automatic generation of a code by the corresponding field line coding unit. The contacts of the transmitting relay at the field location alternately apply and remove a shunt from the line. When the line is shunted there is an increase in line current that results in an impulse in the secondary of the impulse transformer. When the shunt is removed from the line the impulse in the secondary of the impulse transformer reverses in polarity. The relay designed as OR is of the polar type and operates its contacts in one direction when it is energized with one polarity and in the opposite direction for the opposite polarity. The OR relay has the further characteristic that its armature remains in the position to which it was last moved even though the current through its winding be reduced to zero. It will thus be evident that the relay OR reproduces in the office the operation of the T relay in the field. The contacts of the OR relay deliver pulses of energy to the office line coding unit which functions to display the information on the proper panel of the C.T.C. machine.

You will observe that a low pass filter is used between each station and the line. The purpose of the low pass filter is to pass the direct current pulses readily and to offer high impedance to frequencies in the general range of 100 cycles and upward. The low pass filters serve also to remove the electrical noises from the line which otherwise would exist with the alternate opening and closing of the transmitting contacts.

This use of low pass filters permits the two wires of the Centralized Traffic Control system to be used for voice frequencies and thus serve as the conducting path for the way station phones. It is general practice to have a way station phone at each end of each passing track and at some other locations where they may be used to advantage. On first thought it might appear that way station phones would not be needed with Centralized Traffic Control. They do serve a very useful purpose, however, in the event of a train crew desiring a special arrangement such as the local freight desiring to occupy the main line for working purposes in connection with the dropping off and picking up of cars. Also, if a train remains in a siding a greater length of time than usual, a member of the train crew can readily go to the phone and inquire in regard to the reasons for the delay. It is thus very important to have a good communication circuit with each C.T.C. installation and this can be provided very economically by using the line wires of the Centralized Traffic Control system.

The system is arranged in such a manner that one or all field stations may start to transmit codes at the same time. The stations have a prearranged priority so that in any instance of this kind only one field station succeeds in transmitting its information to the office. The remaining field stations which have information to transmit to the office store the information and deliver it to the office in accord with their priority. It is not considered to be within the scope of this paper to explain in detail how this priority is established, but it is based upon a station being permitted to continue in transmission as long as the code it is receiving is exactly the same as the one it is transmitting. "Inferior" stations are "locked out" because of disagreement between the received and transmitted codes.

Practice has indicated that about 30 stations operating in the manner that has been described is the maximum number to use on one d.c. line circuit for a moderately busy single track railroad. For the very busy single track road the number of stations is frequently reduced to somewhere in the order of 20. One operator, however, can handle a much greater number of stations than the 20 or 30 referred to so there was the problem of expanding the system without requiring more line wires. The need for working on a minimum number of line wires was of extreme importance during the war when copper was such a critical material. The general principle which was adopted at that time and which continues to be standard for large installations is to divide the territory into sections of 20 to 30 stations each. The length of each section is usually in the order of 50 to 100 miles.

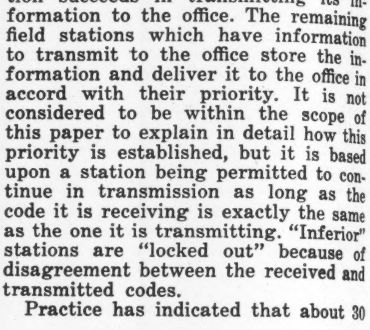

Fig. 10

Let us now explain how it is possible to control two or more sections in one direction from the office over a single pair of line wires. Fig. 11 shows a three-section installation and the principles there shown may be extended to control a greater number of sections. The section nearest the office, AB, is handled in the conventional manner with a multiple line circuit provided with low pass filters as shown in Fig. 10. The second section, BC, is installed in the field in exactly the same manner as if the office for that section were located at point B. The two sections are insulated from one another as far as direct current pulses are concerned. Each section has its individual line battery and functions independently of the other. Instead of the office for section BC being located at B, it is at point A and connection is established between these two points by means of carrier frequencies transmitted over the line wires of the near section. When a control code is originated for the second section it will leave the machine as coded carrier pulses that will be transmitted over the line wires of the near section. There is a carrier responsive relay at point B which will respond to the coded carrier and over the contacts of this relay d.c. pulses will be applied to the second section. Codes originating in the second section will be transmitted to point B by means of d.c. pulses and a d.c. pulse responsive relay at point B will apply carrier pulses to the line wires of the near section. These pulses will be delivered to the office and result in the displaying of the information on the proper panel of the machine.

The section CD is installed in the same general manner as section BC. A separate pair of carrier frequencies is used for establishing the connection between the office and point C. The same general principles are used as described in connection with the control and indication codes for section BC. The carrier frequencies 1 and 3 for section BC and 2 and 4 for section CD are selected above the voice range so there will be no interference between the voice and carrier circuits. You will observe that the low pass filters which were applied to permit the use of voice frequencies on the line serve also to permit the line to be used for the transmission of carrier frequencies. The three-section installation just described is typical of many of the large installations that were placed in service during the war. The installations have continued to grow in size since the war and at the present time there are installations in service having as many as six sections in one direction from the office. The longest Centralized Traffic Control line measured in one direction from the office that is in service at the present time is 409 miles. In some instances the length of line and the amount of traffic are such that more than one man is required for the operation of this territory.

A communication problem was introduced when the Centralized Traffic Control lines became of such length that two operators were required. It was then necessary to establish a separate communication circuit from each operator to the territory over which he has control. The entire territory is devided into two parts as far as voice frequencies are concerned. The one operator carries on conversations with the near half of the line by using the conventional physical circuit. The way station phones on the remote half of the line are installed in the standard manner thus permitting conversation between any two points on the remote half of the line independently of the conversations on the near half of the line. A duplex carrier communication circuit is used over the line wires of the near half of the line to establish communication with the second operator.

There is the need for an additional communication circuit for use of the maintenance and test personnel. This is provided by using portable carrier telephone equipments operating on a frequency different from that used by any of the other facilities. A carrier frequency of 35 kc. is becoming rather standard for this type of service. Small portable carrier telephones have been developed to operate on this frequency

It has not been considered to be within the scope of this paper to go into detail in regard to the various filters and repeaters that are required for the multiplicity of functions that are handled over this one pair of line wires. It will be obvious that the old saying "don't put all your eggs in one basket" has not been followed in this work. The principle that has been adopted might be stated, "When you put all of your eggs in one basket be sure you have a strong basket". Extremely strong and rugged line construction is recommended for a C.T.C. system and having this very reliable line available, it is reasonable that all facilities that can be handled economically be placed on this line. This general principle has proved itself to be sound as evidenced by the continuing increase in the lengths of lines of this type on the many railroads in this country.

The extensive use of carrier frequencies results in a system which gives quite good Centralized Traffic Control performance under broken wire conditions. Largely because of electrostatic coupling the carrier frequencies are transmitted past a break in one wire. "Stand-by" repeaters may be cut in automatically or in response to a control code from the operator to introduce a gain to counteract the attenuation offered by the broken wire. In the usual instance a broken line wire interfered only with the operation of the field stations in the one "section" that are located beyond the break. All "sections" beyond the break continue with normal performance.

A short circuit between the line wires would interfere with the operation of all stations beyond the fault. A high degree of protection is afforded against this condition.

(1.) By the design of the circuit so that the fault must have quite low resistance before it will interfere with operation.

(2.) It is usual practice to use well insulated line wires so faults will not be produced by other line wires falling on the C.T.C. line or by miscellaneous metallic parts coming in contact with the line wires.

There are two interesting by-products from the maintenance standpoint resulting from having communication services on the Centralized Traffic Control line.

(1.) If a severe storm should destroy a part of the line, it is possible to restore service promptly because only one pair of wires is required and in most instances this can be handled by an emergency twisted pair.

(2.) It has been found from experience that a Centralized Traffic Control line operating in accord with the principles discussed in this paper will continue to give reliable service even though faults on the line may produce so much noise that the voice circuit may not be usable. The quality of the voice circuit thus gives advance warning of fault conditions which usually may be corrected before they become serious enough to interfere with the reliable operation of the Centralized Traffic Control system.

In conclusion I should like to leave with you the following: The basic principles and fundamentals of railway signaling are quite old and yet the systems make use of modern techniques such as carrier and electronics in novel ways. The development groups engaged in this field find the work very interesting and they derive a special gratification from making contributions which add to the safety for the traveling public and to the economy of operation of the railroads.

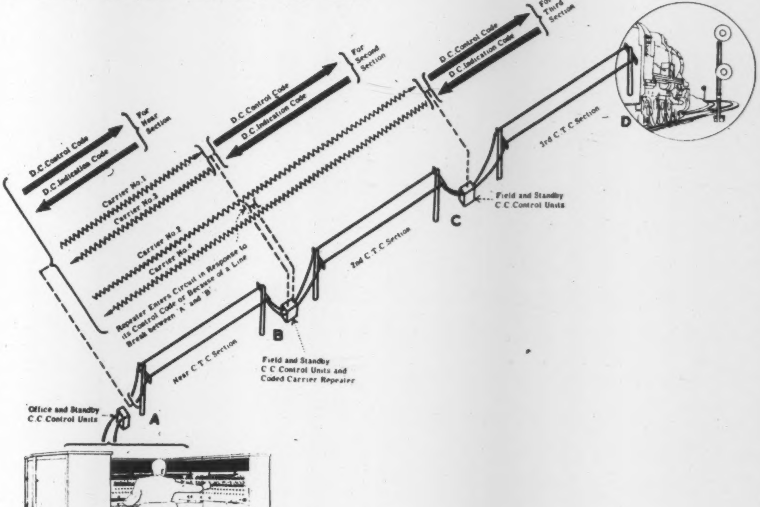

Fig. 11.

New York Regional Conference

The following material has been reprinted from the December 1950 issue of the *New York Integrator*, publication of the New York Section, ISA.

NOTES ON JANUARY CONFERENCE

By C. J. Zeller, Conference Chairman

"Process Controls" is the topic of the 1951 Conference to be held by the New York Section of the Instrument Society of America.

This topic follows those of our previous conferences in a perfectly natural sequence, and because of the wide field covered by the coming conferences, it is expected to have unusual appeal to those concerned with process control and the instrumentation involved.

A review of the schedule for the Friday, January 26, session will reveal that our speakers include some of the recognized leaders in the field of process control. The subject matter covers basic principles, pneumatic operators, effect of distance on stability, new concepts, controlling continuous processing, electrical controllers and process instrumentation in the nuclear field.

The opening address of the Saturday, January 27, session will describe the process factors which effect automatic control. Following this, six of the leading manufacturers of process control instruments will hold a service clinic to make clear to the operating and maintenance personnel the procedure for maintaining their instruments in the best operating conditions. These six clinics will run concurrently throughout the day and will be divided into periods of approximately forty-five minutes each so that anyone wishing to do so will be able to visit each of the clinics during the period of the Saturday session.

PROGRAM FOR JANUARY CONFERENCE

To be held at the Hotel New Yorker, 34th Street and 8th Avenue, New York City, Friday, January 26, and Saturday, January 27, 1951.

Friday, January 26

Morning Session 10 AM. to 12:15 PM.
Mr. J. B. McMahon, Chairman
Registration 9 to 10 AM.

1. "Basic Principles of Pneumatics in Reproducing On-Off, Proportional, Reset and Derivative Control Actions." C. E. Mason, The Bristol Co.
2. "Pneumatic Operators for Throttling Control." R. B. Werey, Conoflow Co.
3. "The Effect of Transmission Distance on the Stability of Flow Control Processes." D. B. Kirk, Moore Products Co.

Afternoon Session 1:30 PM. to 4:30 PM.
Prof. C. F. Kayan, Chairman

4. "A New Concept in Controller Action (Tri-act Control)." R. E. Clarridge, Taylor Instrument Cos.
5. "Controlling Continuous Processing Using Centralized Pneumatic Systems." Ward O'Connor, The Lummus Co.
6. "Electrical Process Controllers, Types and Application." W. W. Winters, Automatic Temperature Control Co.
7. "Process Instrumentation in the Nuclear Field." Dr. V. L. Parsegian, Director, Div. of Technical Advisors, A.E.C., N. Y.

Saturday, January 27

Mr. J. W. Bennett, Chairman
Registration 9 to 9:30 AM.

1. Opening Address: "Process Factors Which Effect Automatic Control." J. B. McMahon.
2. Maintenance Clinic by Manufacturers' Representatives. 10:30 AM. to 12:30 PM.
3. Maintenance Clinic continued. 2 to 4 PM
4. Closing Address by Mr. Bennett.

Manufacturers' Representatives participati in the Maintenance Clinic include: Automati Temperature Control Co., Inc.; The Bristol Co. Energy Control Co.; Republic Flow Meters Co. Tagliabue Corp. of New Jersey; Taylor Instru ment Cos.

Letter Praises 1950 Conference

Dear Mr. Rimbach,

As a visitor from overseas privileged to a tend the I.S.A. Convention at Buffalo in Sep tember last, I feel that the Society is to be con gratulated on a well organized meeting and i strument exhibition.

It very obviously afforded an excellent o portunity for a very profitable meeting betwee the user and the maker to discuss mutual prob lems, and if any criticism might be levelled i could only be that with so many papers on sub jects of interest, it was impossible to attend the all, without dividing oneself in two parts o risking mental indigestion.

It was noticeable that the papers were on severely practical level, which is always of mor interest to a potential user than the inclusio of too much academic detail. The discussion also were eminently practical, and in some cases extremely lively, indicating the keen spirit o competition among the manufacturers, and re flecting keen interest and knowledge of instru ment technology on the part of the user.

The range of the exhibits showed the very wide interest of the I.S.A., and although there were some obvious gaps in the range of products shown this year, the exhibits indicated that the instrument industry was well prepared to cater for the needs of the user in all spheres of measurement and control.

The social events provided a welcome relaxation, and a very good opportunity for members to become better acquainted personally, and showed also that the members' capacity for enjoyment is at the same high level as their attitude towards the job in hand.

In conclusion, I should like to wish the I.S.A. the same success in its future conventions.

P. Scanes, George Kent, Ltd.,
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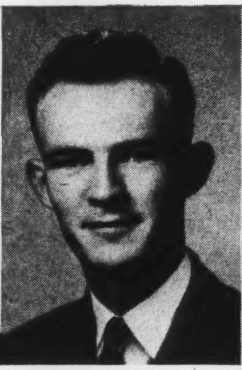

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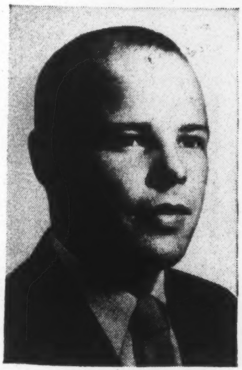

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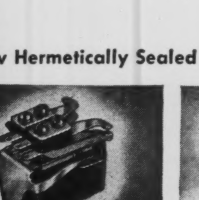

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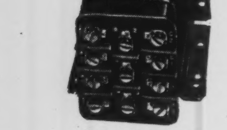

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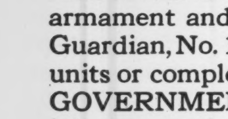

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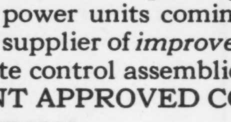

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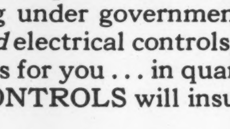

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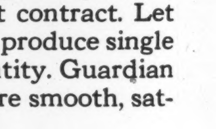

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Locating Underground Pipes

By H. EGGLESTON, Jr., Goldak Co.

I AM very pleased to have the opportunity to talk to you tonight on electronic locating equipment because I have found that throughout the oil and gas industries both here and in the East, there are surprisingly few men who know just what a pipe locator is and what it will do. Of course there are considerably fewer men who know the principles involved in its operation.

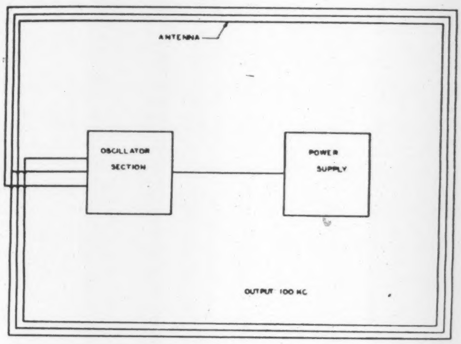

Fig. 1. Transmitting unit.

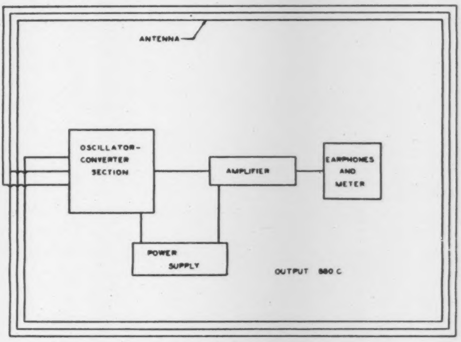

Fig. 2. Receiving unit.

The obvious answer to the question, "What is a pipe locater?" is, it is an instrument for locating pipe. But that's not the whole answer, not by a long ways. The incompleteness of this answer was vividly brought out to me not long ago as I was travelling through a small Eastern town. A tremendous yellow ditch-digging machine was laboring right down the middle of the main street clearing the way for the laying of a 10-inch water main, and I said to myself, "Here's a good spot to sell a pipe locator." After a few minutes chatting with the foreman on the job, I asked him if he had used a pipe locator ahead of his digging operations. He immediately said that he had one. When I asked him if he would care to devulge the name of the set he was using he pointed to the huge yellow machine and said that there was the best pipe locator made. Of course, in addition to locating the pipes it also ripped them out of the ground. He asked for a demonstration, however, and eventually bought an electronic locator.

So you can see that a pipe locator must detect a pipe without bending or breaking it, and it must do quite a bit more. To pay for itself it must be able to trace out the direction of a pipe, accurately pinpoint its location, measure its depth, and locate a dead end. It must be able to trace out a clay or tile line and trace cables and conduits, and separate closely-spaced lines. Furthermore, a pipe locator, and valve locator too, should be capable of detecting valves, curb boxes, meter boxes and manhole covers.

Before we look at the diagrams which explain the "How" of electronic locating instruments, allow me to dwell a few minutes on their history.

Our company back in the early thirties was manufacturing and selling a kit which consisted of various chemicals and elements for the assaying of gold ore, and it was rightfully named The Gold Assay Kit. From this the name Goldak was conceived. Then from the various contacts connected with the marketing of these kits, the need for some sort of gold or treasure locating device became apparent and, before long, the forerunner to the modern type pipe locator was being produced and sold.

FEBRUARY MEETING
"HI-JINKS"
Saturday the 17th, Rio Hondo Country Club, Downey, Calif. Dinner at 6:30 p. m.

Actually, a pipe locator employing an entirely different principle was made and used as early as 1920, but its limitations eventually prohibited its further development. It consisted of five basic parts: a spark coil, a long reel of wire, a receiver coil, a pair of earphones, and a couple of batteries. The procedure was to tie one end of the reel of wire on to a valve stem or on to a service line, run it through the spark coil and batteries and after stretching it out two or three hundred feet tie it again to a remote point in the same pipe system. With the switch on, a spark was generated and a signal impressed on the pipe. Then, whenever the receiver loop was directly over the pipe, an audible buzz was heard in the phones. With this set-up a pipe could be traced for distances up to three hundred feet, but the fact that it was necessary to tie directly to the pipe to trace it (or, in effect, *know* where the pipe was to locate it) along with other obvious limitations, led to the development of the modern two-box locator.

The early two-box locators were a great improvement over the old buzzer type sets, but still had several drawbacks. In addition to weighing anywhere from twenty-five to forty pounds, the circuit components used in those days left a lot to be desired. The tubes were large, with poor characteristics, heavy transformers were employed along with large heavy batteries, and the boxes were cumbersome.

The next and most important change occured along about the middle of

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*Presented at a regular meeting of Southern California Meter Association, November 16, 1950.

World War II when the modern lightweight pipe locator was evolved. Through the use of miniature tubes, portable-type batteries and small hardwood boxes, weight of the complete locator was brought down to about 11 pounds; a weight reduction of about 70 percent. With the aid of illustrations I believe you will be better able to understand the "How" of electronic locating equipment.

The transmitting unit, Fig. 1, is quite simple and consists of three basic components; the oscillator or signal generator, the power supply, and the antenna or loop. The power supply consists of two 45-volt "B" batteries which supply plate voltage to the single tube and one 1½ volt flashlight cell which supplies the filament voltage. The circuit is designed to oscillate at approximately 100 kilocycles and this is radiated into the air and ground by means of a simple antenna. The antenna loop is wound in rectangular form and fitted into the inside perimeter of the box. The oscillator coil is used only when a direct connection is made to the pipe and that particular operation will be explained more clearly with the aid of a subsequent diagram.

The receiving unit, Fig. 2, is slightly more complex, consisting of a receiving antenna, an oscillator-converter section, amplifier, earphones and indicating instrument and the accompanying power supply. In operation, at the time the receiver antenna comes in contact with the lines of force from the transmitting antenna, currents are induced and the 100-kilocycle signal is in effect received and enters the oscillator converter section. There it is mixed and converted to an 800-cycle note, amplified, and finally appears as a tone in the earphones or a deflection on the indicator.

By taking the receiving unit and coupling it with the transmitter by means of an aluminum handle, we are ready to start locating pipe. The next drawing, Fig. 3, shows the two units coupled in this manner. The transmitter is mounted vertically on one end of the handle in a fixed position. The receiver is mounted horizontally on the other end and can be rotated very slightly in the directions indicated by the arrows by turning the thumb screw on the connecting handle. With the transmitter on, while standing in an area free of pipes or underground metallic structures, the 100-kc. signal is radiated through the air and into the ground. These lines of force also cut the receiver antenna and induce currents which produce a signal in the phones. But by rotating the receiver by means of the microtuner screw, the set can be balanced electrically and in one particular position a null is achieved. Null means essentially, nothing or point of no signal. In other words you have tuned the set for a given ground condition. Then when you walk over a pipe, there is a change in the amount of ground conductivity you have tuned to, and the induction balance is upset, producing a tone in the phones and a deflection on the indicator. As the back box or transmitter is the energizing unit, maximum lines of force will be cutting the pipe when this box is directly above it. Therefore when the tone is at a maximum or the reading is at its highest point, the pipe must be directly below the transmitting unit.

Fig. 3 shows the set operated as an induction balance. To receive a maximum signal the pipe is crossed at right angles to it. In other words, assuming we want to locate a main running in the same direction as the street itself, as most utility lines do, we would walk perpendicular to the street or from curb to curb.

It follows that the next step after locating a pipe is to trace it and establish its direction. This can be accomplished successfully with the same setup. As long as the transmitter is over the pipe a maximum signal will be heard and by walking in such a manner that this maximum is kept on the indicator, the pipe can be traced.

However, a simpler and much more effective method of tracing a line is by using the boxes separated. After the line is located the transmitter is disconnected from the handle and set over and above the pipe and parallel to it. The receiver is also taken off the handle and carried by the operator. Taking a look at a rather involved looking drawing (Fig. 4) you will see how this operation is carried out. The transmitter is shown placed over a gas service line and in this position it will induce a signal into the ground which is carried by the pipe itself. Then, whenever the receiver box is over the energized pipe, the lines of force set up by the transmitter and surrounding the pipe cut the receiver antenna and a signal results. This wave pattern is carried through the service line, to the main, along the main pipe

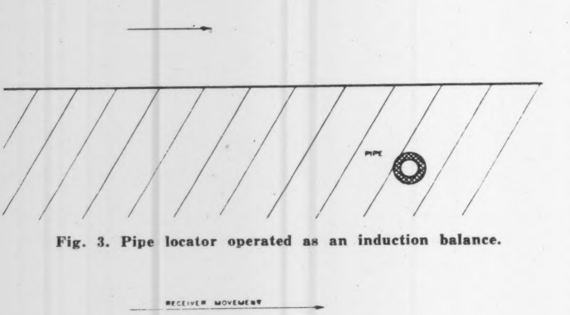


Fig. 3. Pipe locator operated as an induction balance.

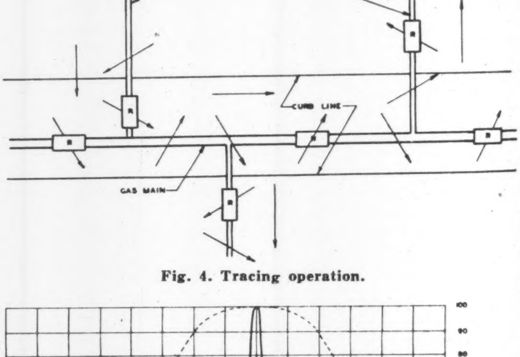


Fig. 4. Tracing operation.

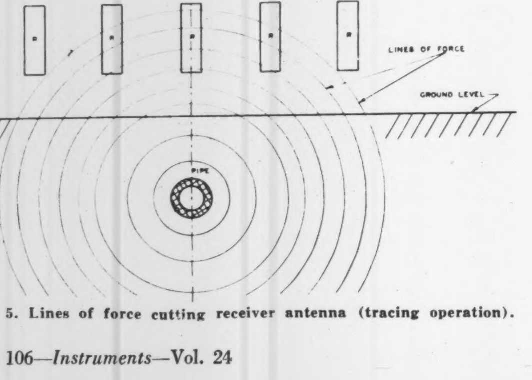


Fig. 5. Lines of force cutting receiver antenna (tracing operation).

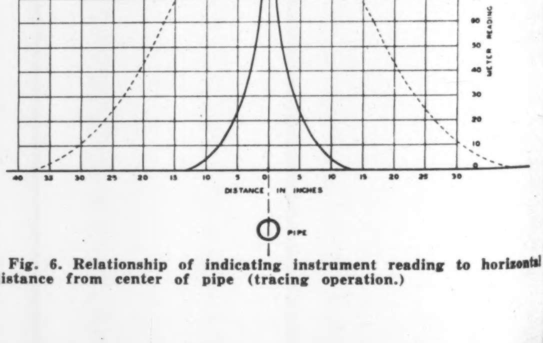


Fig. 6. Relationship of indicating instrument reading to horizontal distance from center of pipe (tracing operation.)

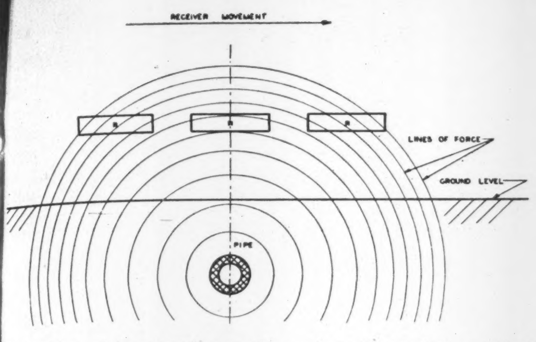


Fig. 7. Lines of force cutting receiver antenna (centering operation).

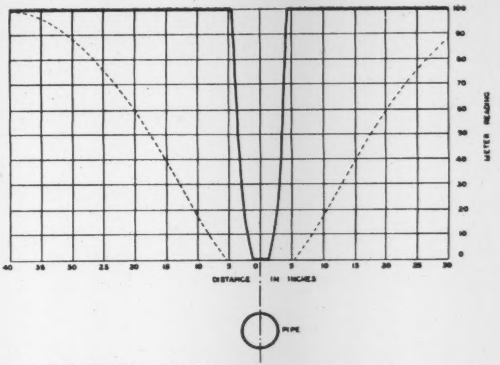


Fig. 8. Relationship of indicating instrument reading to horizontal distance from center of pipe (centering operation).

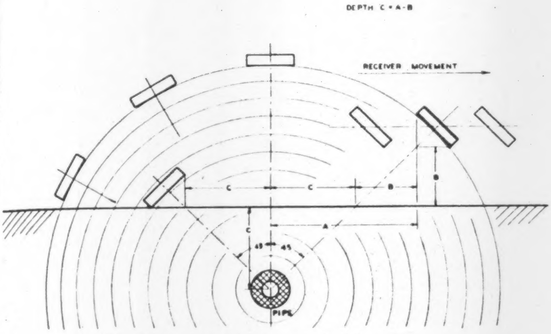


Fig. 9. Measurement of depth of pipe.

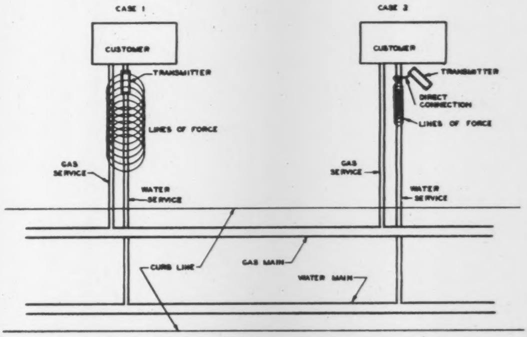


Fig. 10. Separating pipes (direct connection method).

system up to an average distance of two hundred feet from the transmitter. By taking a quick look at the next drawing (Fig. 5) we can see the manner in which those lines of force cut the receiver antenna.

In Fig. 5, the transmitter or energizer is not pictured but is away from us putting a signal into the ground. Successive receiver positions moving from left to right across the pipe are shown. From a point on the extreme left of no signal (no lines of force cutting receiver antenna) to maximum signal (maximum lines of force) to no signal again on the extreme right.

Perhaps this can better be illustrated by a graph, Fig. 6. By letting the horizontal axis represent distance in inches from the center of the pipe and the vertical axis represent the reading, we can see what the effect is of moving the receiver across the pipe. One of the most important characteristics of a good locator is clearly shown here: that of a sharp build-up and sharp cut-off. The broken line represents the signal characteristics of older type locators and many sets in existence today and the disadvantage of this type of curve can readily be seen.

As an example, suppose that two pipes running parallel are only 20 inches apart. Early locators, because of the broad peak and lack of good cut-off characteristics, would show only one pipe with a broad peak halfway between the two existing pipes. Today's locator would show an individual peak over each pipe with a measurable drop in between them.

As I outlined earlier a good pipe locator must accurately determine the location of a given line. This is done by an operation termed "centering" which is shown in Fig. 7. Once again we'll assume that the transmitter is away from us but energizing the pipe shown and setting up the accompanying lines of force. By moving the receiver box across the pipe and parallel to the ground, the pipe can be pin-pointed with respect to its location. When the receiver is in either the left or right position, it can be seen that a maximum number of lines of force are cutting the receiver loop and a maximum reading results. In the center position, however, something else is involved. In that position the plane of the box is tangent to the radiated lines of force and a sharp null occurs. Electrically this takes place because those lines of force are impressed on all sides of the receiver antenna at exactly the same instant. With no time lag present no oscillation takes place and consequently no signal results. This will come up again when talking about depth measurement, but first let's look at the characteristic curve for the centering operation (Fig. 8). This curve shows that a full signal occurs all the way across the pipe with the exception of a very small null area directly over it. Actually the width of the null is less than the diameter of the pipe itself, which gives you an idea what accuracy can be obtained. Again the broken line represents the earlier type of centering characteristic, especially the broad null and long tapering cut-off.

Depth measurement is the centering operation carried one step further, and although the next drawing, Fig. 9, appears complex, the procedure is in reality quite simple. Remember that anytime the receiver box is held tangent to the circular lines of force surrounding the pipe a sharp null occurs. So that at any given angle from a vertical axis through the pipe the box can be tilted in such a way that there is a null. To avoid any complex formulas we choose the 45-degree position to locate the point of null. With the box held at this angle and moved through successive positions, left to right, you will hear the same type of signal as was heard during the centering: full signal, sharp null, and full signal again. At the null point a perpendicular is dropped from the front edge of the box. Then, by measuring the distance from that point to the previously marked center point and subtracting the height of box above ground, you have left the depth of the pipe. Actually this can be simplified further by moving the box away from the pipe right at the ground level, then the horizontal distance on the ground is exactly equal to the depth of the pipe.

The next provision a good locator must have is one for separating closely spaced pipes. There are two methods for doing this and once again the use of drawings will be very helpful. In Fig. 10, Case I shows the difficulty encountered when an attempt is made to trace, by the induction method, one line when it is running parallel to another line only inches away. Assume

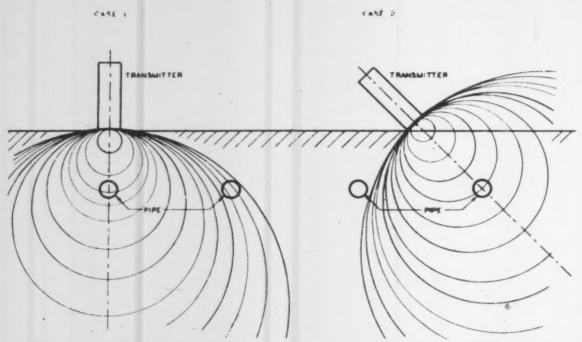


Fig. 11. Separating pipes (slanting transmitter method).

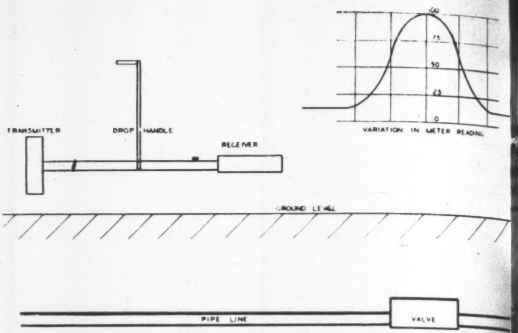


Fig. 12. Locating valves (drop handle method).

for purposes of illustration that it is desired to trace out the water service from the house to the main in order to find the exact tie-in with the main. Assume, further, that the gas service runs parallel with the water service about four inches away, and is about a foot closer to the surface. Normal procedure would be to set the transmitter over the water service. However, the induced signal from the transmitter would cut the gas service in addition to the water service and, because the former is shallower or closer to the ground level, the maximum signal from the receiver would be shown directly over the gas service. In this particular case the end result would not cause too much trouble because the lines are so close together and run parallel to the mains; but should the gas service deviate from the water service the error in tracing would be costly.

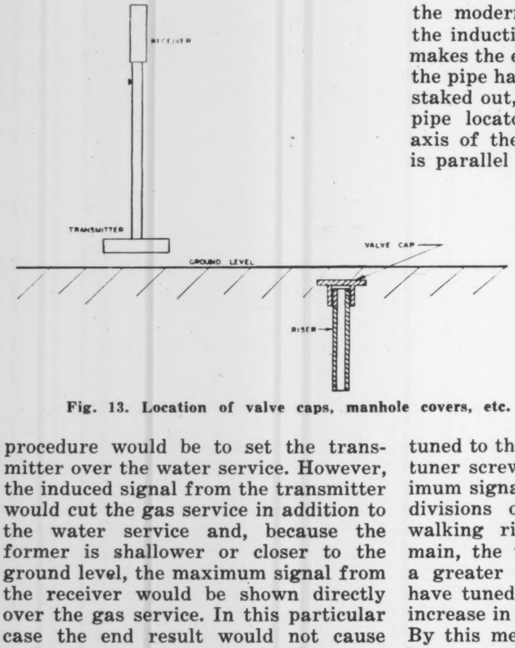


Fig. 13. Location of valve caps, manhole covers, etc.

By switching the set from induction method to direct method the antenna is shorted out and the signal develops in one oscillator coil. This signal is then directed into the pipe by means of a small copper wire tied directly to a point in the pipe or on some external fitting which contacts the pipe. The lines of force surrounding the pipe then do not cut the gas service and the danger of tracing the wrong line is eliminated. This is shown in Case II.

Another method of tracing just one line is done by slanting the energizing unit or transmitter as is shown in Fig. 11. In Case I the lines of force again cut both pipes and the danger of tracing the wrong line is again present. But by slanting the transmitter toward the pipe that is to be traced the lines of force are directed away from the nearby service.

One glaring fault of the old buzzer type sets was the inability to locate valves. This can be accomplished with the modern two box locator by using the induction balance principle. Fig. 12 makes the explanation quite clear. After the pipe has been located and marked or staked out, the procedure is to turn the pipe locator so that the longitudinal axis of the aluminum carrying handle is parallel to the pipe. The set is then tuned to the pipe by rotating the microtuner screw on the handle until a minimum signal is heard, or about 10 scale divisions on the indicator. Then by walking right down the line of the main, the valve, because it represents a greater volume of metal than you have tuned the set to, shows up as an increase in reading and signal strength. By this method it is possible to locate line or gate valves that may or may not have a riser and valve cap.

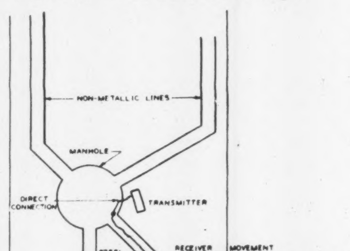


Fig. 15. Tracing non-metallic lines.

An entirely different procedure i used when the valve is known to hav a cap or when locating curb boxes, ga drips, meter boxes or manhole covers. With the aid of Fig. 13 we can show this method. In this operation the se is used on the handle but is not balance inductively. In fact it is intentionall thrown out of balance by rotating th microtuner screw and the result is full signal in the phones. Then, wit the transmitter down and the handl in a vertical position, the area is actually explored by moving the set so as t keep the transmitter as low to th ground as possible. Then, as soon as the transmitting antenna comes in close

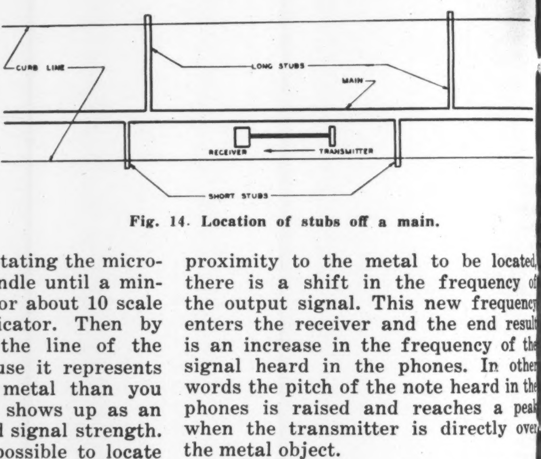
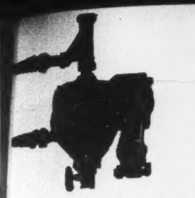


Fig. 14. Location of stubs off a main.

proximity to the metal to be located, there is a shift in the frequency of the output signal. This new frequency enters the receiver and the end result is an increase in the frequency of the signal heard in the phones. In other words the pitch of the note heard in the phones is raised and reaches a peak when the transmitter is directly over the metal object.

This particular method is used ver successfully in cities where street paving is being done, which takes in almost every city. Invariably the paving contractor will come in and pave over all the valve caps before the water o gas company has a chance to raise them to the new grade. And althoug the caps may be only a matter of a few inches under the surface, there still i a locating problem. It also finds grea use in the East where curb boxes ar used on all utility lines.

The Box and Valve Locator is simply the pipe locator in a different mechanical form, consisting of receivin and transmitting antenna, carryin handle, microtuner adjustment, contr box and earphones. In this case bot antenna are used parallel to the groun and are very close together, which



o. 47 Boiler Water
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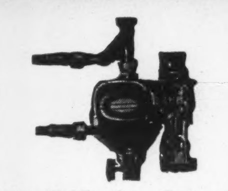
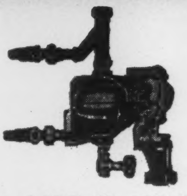
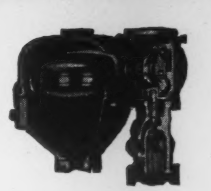


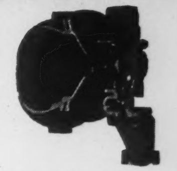
No. 47-2Feeder - Cut - off Combination for automatically fired steam heating boilers up to 5000 sq. ft.



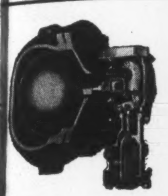
No. 147 Boiler Water Feeder — Similar to No. 47, but with higher feeding level for process steam boilers.



No. 247—Same as No. 47, but for installation with 1" equalizing pipes.



No. 53-2Feeder Cut-off Combination — Similar to No. 51-2, but built for higher pressure, up to 75 lbs..



o. 51 Boiler Water
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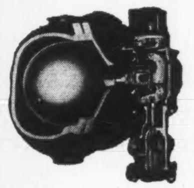
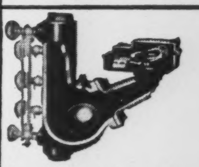


No. 51-2Feeder - Cut - off Combination — for automatically fired steam heating boilers over 5000 sq. ft.

No. 67 Low Water Fuel Cut-off — for low pressure steam boilers of any size.

No. 150 High Pressure Pump Control, Cut-off and Alarm — for steam boilers of any size up to 150 lbs. pressure.



No. 157Water Column Type High Pressure Pump Control, Cut-off and Alarm — for steam boilers of any size up to 150 lbs. pressure.

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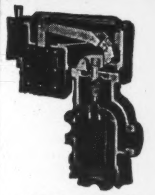

o. 101 Electric Wa-
r Feeder — operated
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witches.

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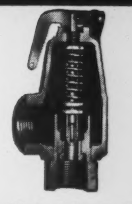

No. 33 Safety Relief Valve — for hot water heating boilers. Btu. rated. ASME standard.

o. E-2 Flow Switch
- Completes (or
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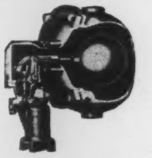
No. 21

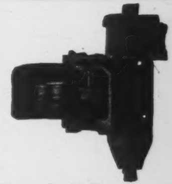
No. 121

No. 321



No. 421

Make-up Water Feeders—to maintain adequate water supply in receiving tanks. Nos. 21, 121 and 321 are installed right in tank openings; available in various flange forms and sizes as shown to fit existing openings. No. 421 is for external application, with equalizing piping.



No. L-8 Constant Level Valve — Maintains constant fuel oil pressure on burner.

o. 417 Snap Action
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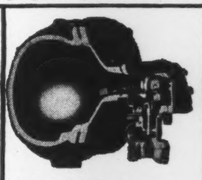
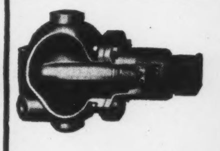
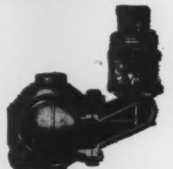
No. 517 Water Level Control — Same as No. 417, but in die cast float chamber with cover.



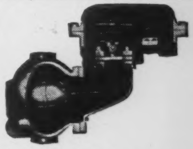
No. 355 Large Capacity Float Valve — Has many uses on tanks, stills, receivers, etc.



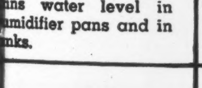
No. 61 Low Water Fuel Cut-Off — for 1" equalizing pipe installation on low pressure steam boilers.



No. 63 Low Water Fuel Cut-off — for water or steam boilers up to 50 lbs. pressure.



No. 65 Explosion-proof Electric Controller — Underwriters' approved for hazardous locations.



. 69 "Built-in" Low
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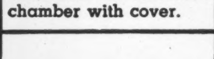
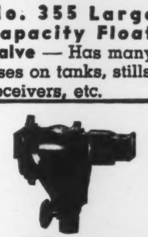
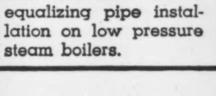


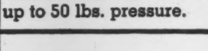
No. 469 "Built-in" Low Water Cut-off— Similar to No. 69, but with less projection into boiler.



No. 767 Low Water Fuel Cut-off — (with No. 14 blow-off) for easy installation into opening in boiler.



No. 80 Switch — Three wire high- or low-level alarm or pump control on oil storage tanks.



No. 6667 Conversion Head — for converting former cut-offs into two-switch types.

No. 154 High Pressure Pump Control — Similar to No. 150, but with open contact switches.

makes the set sensitive only to an object that presents a surface area, such as a valve. The advantage of this feature can be readily seen in the following example. Suppose you are looking for a valve in the intersection of two main streets. In all probability there will be several crossing lines such as a gas main, water main, telephone cable, conduits for traffic signals, etc. To use the pipe locator for the location of this valve would be quite difficult because the set is also sensitive to the crossing lines and a good many different signals would be received. The valve locator, however, with the loops in a horizontal position, is insensitive to an elongated conductor such as a pipe while still being extremely sensitive to the valve. Therefore, the intersection could be explored with the only signal received reaching a maximum directly over the valve.

In this instrument the component parts of the transmitter and receiver, more specifically, the oscillator, converter, amplifier and power supply, are combined in one box. The antenna leads run from the box through the handle to the exploring head. The operation is quite simple. It consists of plugging in the phones which turns the set on, balancing the two loops inductively by rotating the microtuner screw, just as is done with the pipe locator, and then exploring the given area.

There are two more important problems which a good pipe locator should help solve, and I would like to explain them very briefly. Fig. 14 shows the first problem and that is the location of short stubs or laterals off of a main. The main difficulty encountered in the solution of this problem is the fact that the stub to be located is not of sufficient length to carry much of a signal. For this reason it is sometimes quite difficult to locate stubs by the tracing method as was shown on an earlier drawing. A more successful approach is to use the set balanced inductively on the connecting handle, employing the drop handle extension. By walking parallel to the main and just a foot or two to the stub side an increase in the reading will occur when the transmitting unit is directly over the stub.

The final problem we will discuss is one of tracing the path of clay or tile lines. The simplified drawing, Fig. 15, pictures the operation. Obviously the clay or tile line is not capable of conducting an electric current, so it is impossible to trace them inductively as we would a metallic pipe. The procedure consists of running a steel tape or plumber's line into the clay line a distance of 100 or 200 feet. Then, by using the set on "direct" and making a direct connection between the tape and the transmitter, the direction of the non-conductive line can be traced just as an ordinary utility service line is.

Now with the aid of the small tabletop demonstrator, the Lucite model pipe locator and the box and valve locator, I will attempt to show you very briefly this equipment in operation.

[Demonstration]

Manufacturers' New Literature

In this department we report new literature pertaining to Instrumentation, received from the manufacturers. We urge readers to request ONLY those bulletins which will be of value to them. Use the Postage-free Order Card on Page 115.

Requests for literature FROM ABROAD should be made on company letterhead and mailed DIRECTLY to the manufacturers.

T-1—INTERVAL TIMER. 2-page Bulletin 130C illustrates and describes maker's interval timer designed without external housing, especially for built-in applications; covers features, construction, time ranges and price list.—The R. W. Cramer Co., Inc., Centerbrook, Conn.

T-2 PAPER TESTING INSTRUMENTS. 2-page Leaflet P-500 describes and illustrates maker's line of paper testing instruments including—formation, tearing, strength softness, stretch and gummed tape testers; pulp and filter classifiers.—Thwing-Albert Instrument Co., Penn St. and Pulaski Ave., Philadelphia 44, Penna.

T-3 DYNAMIC AIR PRESSURE MEASUREMENT. 8-page bulletin (Form SA5-950) contains discussion on correcting measurements for phase and amplitude errors in tubing-connected pressure sensing cells; includes types and capacities of maker's cells.—Electronic Associates, Ltd., 778 El Camino Rd., San Carlos, Calif.

T-4 CHARTS, SCALES AND RULES. 44-page Catalog No. 9 illustrates and describes maker's line of glass custom made and standard charts, scales and rules, staging fixtures and accessories for optical comparators.—Engineers Specialties Div., The Universal and Colorplate Co., Inc., 980 Ellicott St., Buffalo 9, N. Y.

T-5 ACCELEROMETER CALIBRATION. 4 page No. 17 issue of house organ, "Instrument Notes," contains article on "Basic Method for Accelerometer Calibration" and new developments on accelerometer.—Statham Laboratories, Inc., 9328 Santa Monica Blvd., Beverly Hills, Calif.

T-6 RECORDING ELECTRIC POWER. 40 page house organ, Vol. 4, No. 6 issue of "Electronic Pneumatic Mechanical Instrumentation" features articles on recording electric power, process instrumentation, quality control and pH control; also new literature and new product items.—Industrial Div., Minneapolis-Honeywel Regulator Co., Philadelphia 44, Penna.

T-7 PRODUCTION MONITORING. 4-page house organ Bulletin No. 950, "The Graphic," features article on "Industrial Production Monitored by Automatic Recorders."—The Esterline-Angus Co., Inc., P. O. Box 596, Indianapolis 6, Ind.

T-8 METERED PUMPING. 2-page Bulletin 295 describes and illustrates maker's "Pulsafeeder" with chemical porcelain pumping head for metered pumping of liquids such as acids, metallic salt solutions and chlorinated hydrocarbons.—Lapp Insulator Co., Le Roy, N. Y.

T-9 SOLDERING TIPS. 20-page booklet-size guide to soldering; contains table on proper fluxes to use and numerous "do's" and "don'ts" of soldering.—Weller Electric Co., Easton, Penna.

T-10 MICROCHEMICAL INSTRUMENTS. 24-page catalog illustrates and describes maker's line of instruments in the field of microchemical analysis.—Micro-Metric Instrument Co., 2891 E. 79th St., Cleveland 4, Ohio.

T-11 ELECTRIC SOLDERING IRONS. 4-page bulletin illustrates and describes maker's line of electric soldering irons in hachet, screw tip and plug tip type iron.—Hexacon Electric Co., Roselle Park, N. J.

T-12 FLOWMETER. 4-page Bulletin 1050 describes and illustrates maker's line of flowmeters and tachometer; gives available sizes, specifications and applications.—Potter Aeronautical Co., 87 Academy St., Newark 2, N. J.

T-13 MERCURY RELAYS. 4-page catalog describes and illustrates maker's line of heavy-duty 1, 2, and 3-pole mercury plunger relays and sensitive relays.—Ebert Electronics Corp., 185-09 Jamaica Ave., Hollis 7, N. Y.

T-14 VISCOMETERS. 4-page booklet entitled "What Users Say about Their Brookfield Viscometers."—Brookfield Engineering Laboratories, Inc., Stoughton, Mass.

T-15 LIQUID-LEVEL CONTROLLERS. 8-page Catalog-Section 1 describes and illustrates maker's line of liquid-level controllers; lists advantages, operation and applications.—Magnetrol Inc., 2110 S. Marshall Blvd., Chicago 23, Ill.

T-16 PNEUMATIC METERING PUMP. 2-page Bulletin 296 describes and illustrates maker's "Auto-pneumatic Pulsafeeder," responsive to variable flow, pH, temperature and liquid level-pressure; includes typical applications.—Lapp Insulator Co., Le Roy, N. Y.

T-17 PORTABLE GAS INDICATOR 2-page Bulletin 30 illustrates and describes maker's new portable non-explosion proof gas indicator to safeguard against flammable or explosive gases and vapors.—Lor-Ann Instrument Co., 58 Montgomery St., Jersey City 2, N. J.

T-18 TIME-DELAY GENERATOR. 4-page bulletin describes and illustrates maker's time-delay generator; complete specifications and data. —Rutherford Electronics Co., 3724½ S. Robertson Blvd., Culver City, Calif.

T-19 METALLIC BELLOWS. 8-page reprint from "Product Engineering" July 1950 entitled "What to Consider When Selecting a Metallic Bellows."—Clifford Mfg. Co., 152 Grove St., Waltham 54, Mass.

T-20 INSTRUMENT MAKERS FACE DEFENSE PROBLEMS. 8-page house organ, Vol. 2, No. 1 issue of "Instrument News," contains an article by W. J. Murphy of ACS on the role and problems of instrument makers in the current crises; also includes articles on instruments in medical research and new developments in maker's line of instruments.—Perkin-Elmer Corp., Danbury Road (Rt. 7), Danbury, Conn.

T-21 RECORDERS, CONTROLLERS. 8-page Bulletin Z6600 Illustrates and lists in condensed catalog maker's line of recorders, controllers, indicators, combustion safeguards and control accessories.—Wheelco Instruments Co., Chicago 7, Ill.

T-22 ELECTROCHEMICAL MEASUREMENTS. 24-page Technical Bulletin No. B51-2 discusses: 1. The concepts of chemistry used in electrochemical measurements, 2. Hydrogen ion concentration (pH), 3. Oxidation-reduction (Redox) potential, 4. Electrolytic conductivity, 5. Final control elements for automatic control systems (pH—Redox—conductivity).—Industrial Div., Minneapolis-Honeywell Regulator Co., Philadelphia 44, Penna.

T-23 CHEMICAL PORCELAIN. 28-page Bulletin 244 contains general description and characteristics of maker's line of chemical porcelain; describes and illustrates valves, pipe and fittings, Raschig rings, towers and special shapes from this material.—Process Equipment Div., Lapp Insulator Co., Le Roy, N. Y.

T-24 RECORDING INSTRUMENTS. 8-page Catalog 114OB describes and illustrates maker's line of dairy recording instruments and other related indicating and recording instruments for temperature and pressure.—TAGliabue Instruments Div., Dept. 67, Weston Electrical Instrument Corp., 614 Frelinghuysen, Newark 5, N. J.

T-25 OPTICAL COMPARATOR FIXTURE BASES. 2-page bulletin describes and illustrates maker's line of fixture bases for optical comparators; includes area of working surface and prices.—Engineers Specialties Div., 980 Ellicott St., Buffalo 9, N. Y.

T-26 PRODUCTION COUNTERS. 2-page folder illustrates maker's line of industrial counters; lists features and advantages.—Durant Manufacturing Co., 1990 N. Buffum St., Milwaukee 1, Wis.

T-27 TEMPERATURE CONTROL. 2-page folder describes and illustrates maker's "Electromax" controllers and applications such as pickling, drying, molding and calibrating.—Leeds and Northrup Co., 4908 Stenton Ave., Philadelphia 44, Penna.

T-28 FLEXIBLE SHAFTS. 12-page Bulletin 5008 describes and illustrates maker's line of flexible shafts; covers construction, characteristics, casing, and attaching end fittings.—S. S. White Industrial Div., Dental Mfg. Co., 10 E. 40th St., New York 16, N. Y.

T-29 INSTRUMENT CASES. 4-page leaflet covers maker's line of cases for particular applications.—Rueckert Mfg. Co., Sprague St., Providence, R. I.

T-30 SWITCHES. 2-page October 1950 house organ, "The Ohmite News" features articles on a-c. use of "slow-break" switch action.—Ohmite Mfg. Co., 4835-41 Flournoy St., Chicago 44, Ill.

T-31 SPRING DESIGN AND QUALITY CONTROL COURSES. 8-page Vol. 1, No. 2 bulletin of plant course offered by Hunter Spring Co. lists requirements, staff, purpose and agenda of tuition-free courses.—Hunter Spring Co., Landsdale, Penna.

T-32 GAS DETECTORS. 8-page catalog discusses maker's line of gas indicators and automatic control systems for use where combustible gases and solvents are used, stored or handled.—Lor-Ann Instrument Co., 58 Montgomery St., Jersey City 2, N. J.

T-33 VOLTMETERS. 12-page Catalog 14 describes and illustrates maker's line of voltmeters; includes characteristics, specifications and tables.—Ballantine Laboratories, Inc., Boonton, N. J.

T-34 SOCKETS AND BASES. 8 catalog pages illustrate and describe maker's miniature plug-in bases and sockets and non-interchangeable base and sockets; includes design features, applications, engineering diagrams.—Alden Products Co., 117 N. Main St., Brockton 64, Mass.

T-35 MASS-SPECTROMETER TUBES AND COMPONENTS. 12-page bulletin illustrates and describes maker's tubes and components for conventional and RF spectrometers; covers advantages, design factors, types of spectrometers, ion source, sample tests and specifications.—General Electric Apparatus Dept., 535 Smithfield St., Pittsburgh 22, Penna.

T-36 PROPORTIONING PUMPS. 8-page Bulletin 299 describes and illustrates maker's piston-diaphragm proportioning pumps giving sizes and ratings; includes section on maker's chemical porcelain valves, joints, fittings and special shapes.—Lapp Insulator Co., Inc., Le Roy, N. Y.

T-37 PRESSURE TRANDUCERS. 10 pages, Bulletin No. 3. 1 Sec. C & D and price list contain articles on differential pressure tranducers and absolute pressure tranducers; includes tables covering specifications and data.—Statham Laboratories, 9328 Santa Monica Blvd., Beverly Hills, Calif.

T-38 INDUSTRIAL PACKAGING. 4-page house organ, Vol. 6, No. 3 issue of "Uses Unlimited," features article on switch-equipped machine wrapping as compared to hand wrapping.—Micro Switch, Freeport, Ill.

T-39 VALVE APPLICATIONS. 20-page house organ, Vol. 9, No. 5 issue of "The Flow Line," features articles on valve application in the Alcoa Point Comfort Works and Oakland Seneca reservoir; also includes petroleum refinery valve specification guide.—Pittsburgh Equitable Meter Div., Rockwell Mfg. Co., 400 N. Lexington Ave., Pittsburgh 8, Penna.

T-40 LEVELS. 6-page catalog describes and illustrates maker's precision levels for extremely accurate leveling.—Wm. B. Fell Co., 320 McLain Ave., Rachford, Ill.

T-41 ELECTRON MICROSCOPE. 12-page brochure (Form 2J6851) describes and illustrates maker's table model electron microscope; covers

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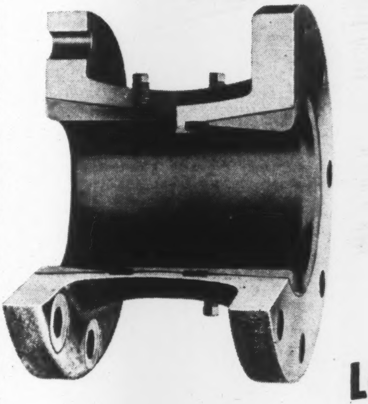

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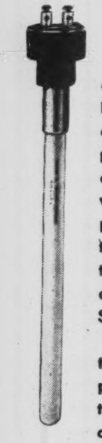

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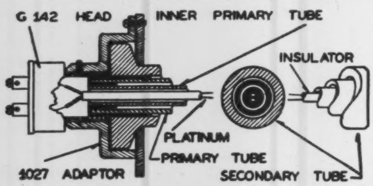

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features, applications, principle.—Dept. 521, Engineering Products Dept., Radio Corp. of America, Camden 2, N. J.

T-42 TRANSMISSION SYSTEMS. 80-page catalog describes and illustrates maker's pneumatic and electric pressure and temperature transmission systems; includes ranges and price lists.—Manning, Maxwell & Moore, Inc., Bridgeport 2, Conn.

T-43 RESISTANCE THERMOMETERS. 12-page catalog illustrates maker's line of instruments and accessories for measuring temperatures in aircraft.—Lewis Engineering Co., Naugatuck, Conn.

T-44 PORTABLE GAS INDICATOR. 2-page Bulletin 20 illustrates and describes maker's new portable explosion-proof gas indicator for combustible gases, Class 1, Group D hazardous locations.—Lor-Ann Instrument Co., 58 Montgomery St., Jersey City 2, N. J.

T-45 VOLT-AMMETER. 16-page Manual No. 110 entitled "How to Make Your Job Easier with the Amprobe" describes and explains the details on how to use maker's snap-on volt-ammeter and how to read the scales.—Pyramid Instrument Co., 49 Howard St., N. Y. 13, N. Y.

T-46 TV AND FM SERVICING INSTRUMENTS. 2-page illustrated folder describes 6 of maker's line of FM and TV servicing instruments; includes information on sizes, weights, ranges and prices.—The Simpson Electric Co., 5200 W. Kinzie St., Chicago 44, Ill.

T-47 PHASE SEQUENCE INDICATOR. 2-page Bulletin 7A illustrates and describes maker's phase sequence indicator for working with polyphase electrical circuits.—Associated Research Inc., 3766 W. Belmont Ave., Chicago 18, Ill.

T-48 SPRING-ACTION CONTACTS. 22-page Catalog 161 illustrates and describes maker's attachment plug caps, cube adapter, cube taps, rectifier bulbs, spring-action contacts, etc.; includes technical data and price list.—Sheldon Electric Co., Div., Allied Electric Products Inc., 68-98 Coit St., Irvington 11, N. J.

T-49 DRAFTING BEAM COMPASS. 6-page pamphlet illustrates and describes maker's beam compass for precision inking and pencil drafting as well as scribing on metals.—V. & E. Mfg. Co., Pasadena, Calif.

T-50 RADIOACTIVITY COUNTER. 2-page bulletin illustrates and describes maker's "Raytomic" radiation counter; covers uses and features.—Atomic Research Corp., Peterson Field. Colorado Springs, Colo.

T-51 FLIGHT TRAINING INSTRUMENTS. 4-page issue of this house organ, Vol. VII, No. 3, "The Connecting Link" features articles on Naval Air Training Program and high-speed, high-latitude celestial navigation trainer.—Link Aviation, Binghamton, N. Y.

T-52 ELECTRICAL TESTING INSTRUMENTS. 8-page catalog lists electrical testing instruments of new surplus guaranteed stock; all items unused and unmounted.—Maritime Switchboard, 336-340 Canal St., New York 13, N. Y.

T-53 VIBRATION TEST EQUIPMENT. 4-page Booklet 4401 illustrates and describes maker's 450-pound force shaker and 2 to 500 cps. power supply.—The Calidyne Co., 751 Main St., Winchester, Mass.

T-54 RECORDING INSTRUMENTS. 4-page booklet describes and illustrates maker's recorders with chart of electrical specifications of micromicroammeter, millivoltmeter and microvoltmeter.—Millivac Instrument Corp., P. O. Box 3027, New Haven, Conn.

T-55 POTENTIOMETER. 2-page Bulletin 108 describes and illustrates maker's miniature design potentiometer; lists general specifications, characteristics, and price list.—The Helipot Corp., South Pasadena, Calif.

T-56 GAS LIQUIFICATION. 6-page bulletin illustrates and describes maker's cryostat for liquification of gases; gives specifications and applications.—Arthur D. Little, Inc., Cambridge, Mass.

T-57 ACOUSTICAL MEASUREMENT. 16-page catalog illustrates and describes maker's line of instruments including sound spectrum analyzer, octave filter set, electronic voltmeter, laboratory power amplifier, etc.; includes speci-

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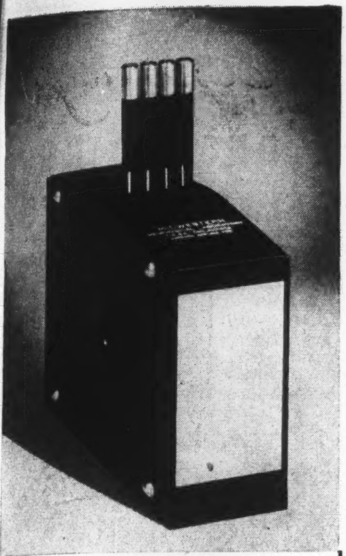

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fications and price list.—Western Electro-Acoustic Laboratory, 204 S. Beverly Dr., Beverly Hills, Calif.

T-58 D-C. POWER SUPPLY. 16-page house organ Vol. 15, No. 11 of "The Capacitor" features article on variable-output, voltage-regulated d-c. power supply; includes 'swap' section, Radio Trading Post.—Cornell-Dubilier Electric Corp., Hamilton Blvd., South Plainfield, N. J.

T-59 BATTERIES. 6-page brochure covers maker's line of small, light-weight rechargeable storage batteries; includes complete specifications.—Yardney Electric Corp., 105-107 Chambers St., New York 7, N. Y.

T-60 ELECTROCHEMOGRAPH. 16-page catalog EM 9-90 (1) illustrates and describes maker's "Type E" electrochemograph for polarographic analysis adaptable to operation from standard 115-v. a-c. supply circuit.—Leeds & Northrup Co., 4907 Stenton Ave., Philadelphia 44, Penna.

T-61 SPRING BUYER'S GUIDE. 8-page bulletin illustrates and describes maker's line of springs in 4 sections; engineering, manufacture, materials and glossary of terms.—Hunter Spring Co., Lansdale, Penna.

T-62 RESEARCH AMPLIFIER. 2-page Form 805 illustrates and describes maker's physiological research amplifier; includes specifications.—Edin Co., Inc., Worcester 8, Mass.

T-63 TRIADE. 4-page house organ Vol. 6, No. 2 issue of "Allied News" features article on 500-kilowatt beam triade, pocket size volt-ammeter, soldering gun, etc.—Allied Radio Corp., 833 W. Jackson Blvd., Chicago 7, Ill.

T-64 DYE PENETRANT INSPECTION. 4-page Bulletin 500 illustrates and describes maker's method of non-destructive, dye penetrant inspection of any shape, contour or size of any metal anywhere.—Dy-Chek Div., Northrop Aircraft, Inc., 1515 E. Broadway, Hawthorne, Calif.

T-65 RADIATION LABORATORY EQUIPMENT. 8-page Bulletin GED-1361 illustrates and describes maker's line of ionization chambers, gamma survey meters, particle accelerators, electronic tubes, regulated power supplies, etc.—General Electric, Schenectady, N. Y.

T-66 INSULATION RESISTANCE TESTS. 4-page house organ No. 3, Vol. 6 issue of "Instrument News" includes articles on resistance tests, "Megger" ground tester and Tachometers.—James G. Biddle Co., 1316 Arch St., Philadelphia 7, Penna.

T-67 VOLTMETER. 4-page house organ Vol. 2, No. 3 of "h-p Journal" features article on "700-megacycle Voltmeter and its Applications."—Hewlett-Packard Co., 395 Page Mill Road, Palo Alto, Calif.

T-68 A-C. D-C. COMPARATOR. 4-page catalog illustrates and describes maker's "polyranger" a-c. d-c. comparator; discusses r-f. measurements, external ranges and internal ranges available.—Sensitive Research Instrument Corp., 9-11 Elm St., Mount Vernon, N. Y.

T-69 D-C. AMPLIFIER. 2-page Form 806 illustrates and describes maker's d-c. amplifier; includes specifications.—Edin Co., Inc., Worcester 8, Mass.

T-70 RHEOSTATS. 2-page house organ, Nov. 1950 issue of "The Ohmite News," features article on application of rheostats on manufacture of television picture tubes.—Ohmite Manufacturing Co., 4835 Flourney St., Chicago 44, Ill.

T-71 INDUSTRIAL THERMOMETERS. 12-page Catalog 100 illustrates and describes maker's line of industrial thermometers; covers applications, scales, cases, range and insulation.—Gotham Instrument Co., Div. of American Machine and Metals, Inc., 233 Broadway, New York, N. Y.

T-72 BOILER WATER FEEDERS. 4-page catalog and enclosed price list illustrates and describes maker's line of boiler water feeders and low water fuel cut-offs.—McDonnell & Miller, Inc., 3500 N. Spaulding Ave., Chicago 18, Ill.

T-73—WASTE NEUTRALIZATION. 8-page house organ, Vol. 10, No. 3 of "Modern Precision," contains several articles on control applications in the process industries, metals,

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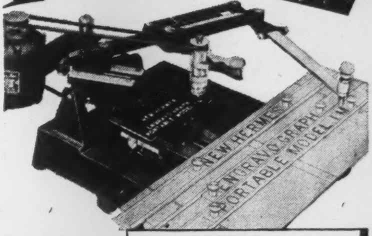

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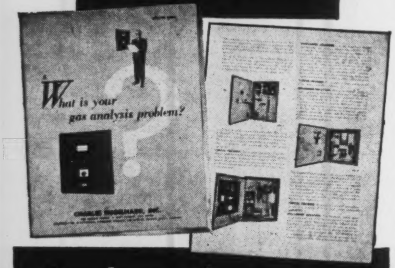

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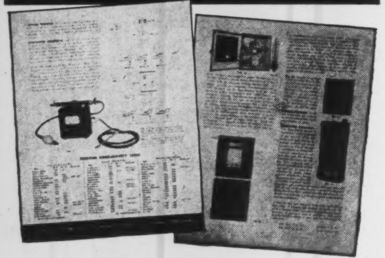

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ceramics, power, research, teaching and testing.—Leeds & Northrup Co., 4902 Stenton Ave., Philadelphia 44, Penna.

T-74 SCIENTIFIC APPARATUS AND METHODS. 30-page Catalog, Vol. 3, Fall 1950 issue, features article on "Polarography of Vitamins" as well as lists of new, reinstated and discontinued items.—E. H. Sargent & Co., 4647 Foster Ave., Chicago 30, Ill.

T-75 PUMPS. 30-page house organ, Vol. 1, No. 1 issue of "The Welch Physics Digest," features articles on physical applications reprinted from leading scientific journals; illustrates and describes maker's "duo-seal" and vacuum pressure pumps, micrometer, densitometer and atom chart.—W. H. Welch Scientific Co., 1515 Sedgwick St., Chicago 10, Ill.

T-76 DIAL-TYPE THERMOMETERS. 16-page Catalog 200 illustrates and describes maker's dial thermometers discussing constructional features, specifications, ranges, connections and tubing.—Gotham Instrument Co., Div., of American Machine and Metals Inc., 233 Broadway, New York, N. Y.

T-77 ELECTRON MICROSCOPE. 12-page brochure discusses maker's "Type EMT" table-model electronic microscope covering features, aplications, principles of operation and operation.—RCA Engineering Products Dept., Camden, N. J.

T-78 X-RAY PHOTOMETER. 8-page Bulletin GEC-412A illustrates and describes maker's x-ray photometer for chemical analyses by x-ray absorption; covers operation, components, specifications.—Apparatus Dep't, General Electric Co., Schnectady 5, N. Y.

T-79 DIELECTRIC MOISTURE METER. 4-page Bulletin 1263A discusses construction, operation and advantages of maker's dielectric-type meter.—TAGliabue Instrument Div., Dept. 67, Weston Electrical Instrument Corp., 614 Frelinghuysen Ave., Newark 5, N. J.

T-80 MAGNETIC OSCILLOGRAPH. 2-page Form 807 describes and illustrates maker's line of magnetic oscillographs.—Edin Co. Inc., Worchester 8, Mass.

T-81 AUTOMATIC VALVES. 8-page Bulletin 299 illustrates maker's line of relief and pressure reducing valves and hot water heat controls.—A. W. Cash Valve Mfg. Corp., Decatur, Ill.

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CONTENTS

EDITOR'S FOREWORD

AUTHOR'S PREFACE

CHAPTER I—ESSENTIAL TOOLS

CHAPTER II—D-C. INSTRUMENTS

Dismounting and Reassembling—KX-124 Instruments—DB-12 Instruments—Test and Inspection—Principles of Operation—Maintenance—Connections.

TROUBLE CHART FOR D-C. INSTRUMENTS

CHAPTER III—A-C. AMMETERS AND VOLTMETERS

Principles of Operation—Construction—Dismantling KA-24 Instrument—Reassembling—Dismantling DB-12 Instrument—Test and Inspection—Internal and External Connections—Maintenance.

CHAPTER IV—ELECTRODYNAMIC TYPE INSTRUMENTS

WATTMETERS—Construction—The KF-24 Wattmeter—The AB-12 Wattmeters—Connections—Principle of Operating—Inspection and Calibration—Single-phase Wattmeter—Polyphase Wattmeter—Maintenance.

FREQUENCY METERS—Construction—The KF-24 Instrument—The AB-12 Instrument—Principles of Operation—Test and inspection—Maintenance.

CHAPTER V—POWER FACTOR METERS AND SYNCHROSCOPES

POWER FACTOR METERS—General Description—Dismounting and Reassembling—Inspection and Calibration—Maintenance.

SYNCHROSCOPES—Description—Inspection and Tests—Maintenance.

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